



**UNIVERSIDADE FEDERAL DO PARÁ
INSTITUTO DE GEOCIÊNCIAS
PROGRAMA DE PÓS-GRADUAÇÃO EM GEOLOGIA E GEOQUÍMICA**

TESE Nº 181

**BRAQUIÓPODES DEVONIANOS DA BACIA DO AMAZONAS:
NOVOS DADOS TAXONÔMICOS,
PALEOBIOGEOGRÁFICOS E RELAÇÕES COM AS
MUDANÇAS AMBIENTAIS**

Tese apresentada por:

LUIZ FELIPE AQUINO CORRÊA

Orientadora: Prof.^a Dr.^a Maria Inês Feijó Ramos (MPEG)

**BELÉM - PARÁ
2024**

Dados Internacionais de Catalogação na Publicação (CIP) de acordo com ISBD
Sistema de Bibliotecas da Universidade Federal do Pará
Gerada automaticamente pelo módulo Ficat, mediante os dados fornecidos pelo(a) autor(a)

C824b Corrêa, Luiz Felipe Aquino.
Braquiópodes devonianos da Bacia do Amazonas: novos dados taxonômicos, paleobiogeográficos e relações com as mudanças ambientais / Luiz Felipe Aquino Corrêa. — 2024.
xxi, 173 f. : il. color.

Orientador(a): Prof^a. Dra. Maria Inês Feijó Ramos
Tese (Doutorado) - Universidade Federal do Pará, Instituto de Geociências, Programa de Pós-Graduação em Geologia e Geoquímica, Belém, 2024.

1. Braquiópodes. 2. Formação Manacapuru. 3. Lochkoviano. 4. Bacia do Amazonas. I. Título.

CDD 560.98115



Universidade Federal do Pará
Instituto de Geociências
Programa de Pós-Graduação em Geologia e Geoquímica

**BRAQUIÓPODES DEVONIANOS DA BACIA DO AMAZONAS:
NOVOS DADOS TAXONÔMICOS,
PALEOBIOGEOGRÁFICOS E RELAÇÕES COM AS
MUDANÇAS AMBIENTAIS**

Tese apresentada por:

LUIZ FELIPE AQUINO CORRÊA

Como requisito parcial à obtenção do Grau de Doutor em Ciências na Área de GEOLOGIA e Linha de Pesquisa Análise de Bacias Sedimentares.

Data de Aprovação: 01 / 10 / 2024

Banca Examinadora:

Documento assinado digitalmente



MARIA INES FEIJO RAMOS

Data: 02/10/2024 09:50:02-0300

Verifique em <https://validar.iti.gov.br>

Prof.^a Dr.^a Maria Inês Feijó Ramos
Orientadora – MPEG

Documento assinado digitalmente



CAROLINA ZABINI

Data: 02/10/2024 10:48:17-0300

Verifique em <https://validar.iti.gov.br>

Prof.^a Dr.^a Carolina Zabini
Membro – UNICAMP

Documento assinado digitalmente

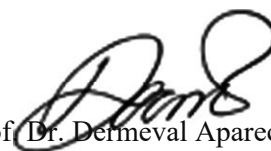



RENATO PIRANI GHILARDI

Data: 02/10/2024 12:57:33-0300

Verifique em <https://validar.iti.gov.br>

Prof. Dr. Renato Pirani Ghilardi
Membro – UNESP


Prof. Dr. Dermeval Aparecido do Carmo
Membro – UnB


Prof. Dr. Joelson Lima Soares
Membro – UFPA

Dedico esse trabalho à minha avó Nair.

Obrigado por tudo!

AGRADECIMENTOS

Em primeiro lugar, queria agradecer a Deus por sempre me proteger.

À Universidade Federal do Pará (UFPA), ao Instituto de Geociências, ao Programa de Pós-Graduação em Geologia e Geoquímica, por toda a infraestrutura disponível e pelo apoio de todos os seus colaboradores: professores, técnicos e alunos, em especial a Cleida Freitas.

O presente trabalho foi realizado com o apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-Brasil (CAPES) – código de financiamento 001.

Ao Campus de Pesquisa do Museu Emílio Goeldi (MPEG), à Coordenação de Ciências da Terra e Ecologia (COCTE), por toda a infraestrutura e apoio de todos os funcionários. Sou muito grato por terem me acolhido tão bem durante esses anos.

À minha orientadora Prof^a Dr^a Maria Inês Feijó Ramos, pela oportunidade, confiança, paciência, ensinamentos, apoio e incentivo. Serei eternamente grato por tudo!

Aos amigos que ganhei ao ingressar no PPGG (Amanda, Bettina, Belinha, Claudia, João, Nayan e Renan). Ao meu amigo Sergio, que me acompanha desde a graduação e ingressou nesse desafio que é a Pós-Graduação junto comigo. Aos amigos que o MPEG me presenteou (Adriana, Katiane, Lorena, Renato, Ana Paula, Yuri, e professor Berrêdo), obrigado por tudo. Aos meus amigos de longa data Bruno, Laura, Dayane, Kassio, Paulo e Wesley. Ao João Rezende, por toda ajuda, dicas e conselhos a respeito deste trabalho.

À minha mãe, Liliam Corrêa, que, apesar de todas as dificuldades, sempre me apoiou e me incentivou, sem dúvida nenhuma, é minha principal professora, conselheira e amiga, a você dedico todas as minhas vitórias. Aos meus irmãos, Lucian Corrêa e Fernanda Corrêa, por sempre acreditarem em mim. À minha avó Cléa, que desde quando eu nasci, participa da minha educação e formação como pessoa. Aos meus padrinhos Sandra e Sebastião, por tudo que fizeram por mim.

À minha namorada, Raiana Grandal, por todo amor, carinho, compreensão e motivação. Obrigado por ser meu combustível, minha amiga e companheira ao longo de toda essa jornada.

Ao meu pai Fernando Corrêa (*in memoriam*), meu principal exemplo de ser humano, meu herói preferido, minha inspiração e motivação diária.

À minha avó/mãe Nair (*in memoriam*) por tudo que fez por mim. Junto com minha mãe, me criou e educou desde os meus primeiros segundos de vida. Sua partida repentina dói muito; nunca irei lhe esquecer.

A minha eterna gratidão a todos!

*“A vida é como andar de bicicleta.
Para manter o equilíbrio, você
precisa ficar sempre em movimento”*

(Albert Einstein)

RESUMO

O Devoniano foi um período importante na história evolutiva dos braquiópodes. Durante esse período, o filo atingiu seu pico de diversidade (Emsiano) e sofreu o seu segundo maior declínio (Frasniano-Fameniano), ficando atrás apenas do evento de extinção em massa Permo-Triássica. Entre as bacias sedimentares brasileiras, a Bacia do Amazonas é a que possui a maior diversidade de gêneros de braquiópodes devonianos, distribuídos entre as seguintes formações: Manacapuru (Lochkoviano), Maecuru (Eoiefeliano), Ererê (Neoeiefeliano) e Barreirinha (Eofrasniano). Os estudos de braquiópodes devonianos da Bacia do Amazonas começaram no final do século XIX com identificações de material coletado durante as "Expedições Morgan (1870-1871)" e a "Comissão Geológica Imperial do Brasil (1876)". Essas expedições se concentraram principalmente nas formações Maecuru e Ererê. A fauna de braquiópodes da Formação Manacapuru (Lochkoviano) era desconhecida até 2015, quando um número significativo de amostras de Rhynchonelliformes e Linguliformes foi recuperado durante salvamento paleontológico na usina hidrelétrica de Belo Monte em Vitória do Xingu, Pará, Brasil. Este trabalho tem como objetivo realizar a identificação taxonômica dos braquiópodes da Formação Manacapuru, além de analisar e discutir os possíveis fatores que influenciaram na diversidade de gêneros de braquiópodes entre as unidades sedimentares da Bacia do Amazonas (formações Manacapuru, Maecuru, Ererê e Barreirinha). O estudo taxonômico dos braquiópodes da parte superior da Formação Manacapuru (Lochkoviano), permitiu, até o momento, a identificação de dois gêneros, *Orbiculoidea* d'Orbigny, 1847 e *Schellwienella* Thomas, 1910. Dentre o material estudado, *Orbiculoidea* tem a maior diversidade, totalizando cinco espécies: *Orbiculoidea baini* Sharpe, 1856, *Orbiculoidea bodenbenderi* Clarke, 1913 e *Orbiculoidea excentrica* Lange, 1943 além de duas novas espécies *Orbiculoidea xinguensis* Corrêa & Ramos, 2021 e *Orbiculoidea katzeri* Corrêa & Ramos, 2021. As espécies *O. baini*, *O. bodenbenderi* e *O. excentrica* são registrados pela primeira vez na Formação Manacapuru e no Norte do Brasil, sendo também os registros mais antigos (Lochkoviano) da América do Sul. A presença de *Orbiculoidea* na região pode ser explicada por dois motivos: a proximidade da Bacia do Amazonas, localizada no noroeste de Gondwana durante o Devoniano Inferior, com o paleocontinente Laurussia (onde são registradas a maioria das ocorrências de *Orbiculoidea* durante o Siluriano), favorecendo o intercâmbio específico entre essas duas regiões geográficas; e a elevação global do nível do mar durante esse período, que inundou grande parte do noroeste de Gondwana, resultando na presença de mares rasos na Bacia do Amazonas, representados por sedimentos marinhos na parte superior da Formação Manacapuru. Essas condições favoreceram

a colonização de braquiópodes inarticulados durante o Devoniano Inferior no norte do Brasil. Ainda, é proposta a nova espécie *Schellwienella amazonensis* Corrêa *et al.* 2024, da Família Pulsiidae Cooper e Grant, 1974, sendo este o primeiro registro do gênero na Bacia do Amazonas. *Schellwienella amazonensis* sp. nov. e *Schellwienella marcidula* Amsden, 1958 da Formação Bois d’Arc (Lochkoviano), EUA, são os registros mais antigos do gênero. No Devoniano, *Schellwienella* ocorreu em todos os estágios (Lochkoviano, Praguiano, Emsiano, Eifeliano, Givetiano, Frasniano e Famenniano), principalmente nos ambientes marinhos siliciclásticos de Gondwana, transitando entre as latitudes temperadas e polares. Já no Carbonífero, sua distribuição estratigráfica se restringiu ao intervalo Tournaisiano-Viséano, e com preferência por ambientes de águas quentes e plataformas carbonáticas, típicas de baixas latitudes. Ao analisarmos a variação da diversidade de braquiópodes devonianos na Bacia do Amazonas, identificamos três estágios distintos. No estágio 1), o pico da diversidade de braquiópodes ocorreu no Eoifeliano (Formação Maecuru), quando a Bacia do Amazonas estava entre as latitudes subtropicais 30°S e 60°S, sob condições marinhas rasas e frias, justificadas pela ausência de carbonatos, evaporitos e recifes na região (Estágio 1). No estágio 2), ocorreu o primeiro declínio da diversidade, registrado na Formação Ererê (Neoeifeliano), atribuído a um clima mais quente e águas mais profundas do que na Formação Maecuru. O estágio 3) ocorreu durante o Frasniano, quando houve um segundo declínio da diversidade de braquiópodes na Bacia do Amazonas (Formação Barreirinha). Uma grande transgressão global ocorreu no final do Devoniano. Nesse período, a Bacia do Amazonas experimentou as condições marinhas mais profundas de sua história. Os braquiópodes da Formação Barreirinha ocorrem em camadas de folhelhos negros (*offshore*), atribuídas a um ambiente disóxico a anóxico de alto estresse, o que explica a baixa diversidade de braquiópodes nesta unidade.

Palavras-chave: *Orbiculoidea*; *Schellwienella*; Formação Manacapuru; Lochkoviano.

ABSTRACT

The Devonian marked a significant phase in the evolutionary history of the Brachiopoda. During this period, the Phylum achieved its peak diversity (Emsian) and suffered one of its most significant declines (Frasnian–Famennian), ranking second only to the mass extinction event Permo-Triassic. Among the Brazilian sedimentary basins, the Amazonas Basin has the greater diversity of Devonian brachiopod genera, distributed among the following formations: Manacapuru (Lochkovian), Maecuru (early Eifelian), Ererê (Late Eifelian), and Barreirinha (early Frasnian). Studies of Devonian brachiopods from the Amazonas Basin began in the late 19th century with identifications of material collected during the Morgan Expeditions (1870–1871) and the Imperial Geological Commission of Brazil (1876). These expeditions focused primarily on the Maecuru and Ererê formations. The brachiopod fauna of the Manacapuru Formation (Lochkovian) was unknown until 2015, when during paleontological salvage at the Belo Monte hydroelectric plant in Vitória do Xingu, Pará, Brazil, a significant number of Rhynchonelliformes and Linguliformes samples were recovered. This work aims to carry out the taxonomic identification of brachiopods from the Manacapuru Formation, in addition to analyzing and discussing the possible factors that influenced the diversity of brachiopod genera among the sedimentary units of the Amazonas Basin (Manacapuru, Maecuru, Ererê, and Barreirinha formations). The taxonomic study of brachiopods from the upper part of the Manacapuru Formation (Lochkovian) has allowed, to date, the identification of two genera, *Orbiculoidea* d'Orbigny, 1847 and *Schellwienella* Thomas, 1910. Among the materials, *Orbiculoidea* has the greater diversity, totaling five species: *Orbiculoidea baini* Sharpe, 1856, *Orbiculoidea bodenbenderi* Clarke, 1913 and *Orbiculoidea excentrica* Lange, 1943 in addition to two new species: *Orbiculoidea xinguensis* Corrêa & Ramos, 2021 and *Orbiculoidea katzeri* Corrêa & Ramos, 2021. The species *O. baini*, *O. bodenbenderi*, and *O. excentrica* were recorded for the first time in the Manacapuru Formation and Northern Brazil, and they are also the oldest records (Lochkovian) from South America. The presence of *Orbiculoidea* in the region can be explained by two reasons: the proximity of the Amazonas Basin, located in the northwest of Gondwana during the Lower Devonian, with the paleocontinent Laurussia (where most occurrences of *Orbiculoidea* are recorded during the Silurian), favored the specific exchange between these two geographic regions; and the global rise in sea level during this period, which flooded much of northwest Gondwana, resulting in the presence of shallow seas in the Amazonas Basin, represented by marine sediments in the upper part of the Manacapuru Formation. These conditions favored the colonization of inarticulate brachiopods during the

Early Devonian in northern Brazil. Furthermore, the new species *Schellwienella amazonensis* Corrêa *et al.* 2024, of the Pulsiidae Family Cooper and Grant, 1974, is proposed, this being the first record of the genus in the Amazonas Basin. *Schellwienella amazonensis* n. sp. and *Schellwienella marcidula* Amsden, 1958 from the Bois d'Arc Formation (Lochkovian), USA, are the oldest records of the genus. In the Devonian, *Schellwienella* occurred in all stages (Lochkovian, Pragian, Emsian, Eifelian, Givetian, Frasnian, and Famennian), mainly in the marine siliciclastic environments of Gondwana, transiting between temperate and polar latitudes. In the Carboniferous, its stratigraphic distribution was restricted to the Tournaisian-Viséan interval, with a preference for warm water environments and carbonate platforms typical of low latitudes. We identified three distinct stages when analyzing the variation in Devonian brachiopod diversity in the Amazonas Basin. In stage 1, the peak of brachiopod diversity occurred in the early Eifelian (Maecuru Formation), when the Amazonas Basin was between subtropical latitudes 30°S and 60°S, under shallow and cold marine conditions, justified by the absence of carbonates, evaporites, and reefs in the region. In stage 2, the first decline in diversity occurred, recorded in the Ererê Formation (late Eifelian), attributed to a warmer climate and deeper waters than in the Maecuru Formation. Stage 3 occurred during the Frasnian when there was a second decline in brachiopod diversity in the Amazonas Basin (Barreirinha Formation). A major global transgression happened at the end of the Devonian. During this period, the Amazonas Basin experienced the deepest marine conditions in its history. Brachiopods of the Barreirinha Formation occur in black shale layers (offshore), attributed to a dysoxic to the anoxic environment of high stress, which explains the low diversity of brachiopods in this unit.

Keywords: *Orbiculoidea*; *Schellwienella*; Manacapuru Formation; Lochkovian.

LISTA DE ILUSTRAÇÕES

Figura 1- Mapa de localização da área estudada. Fonte: Corrêa (2020).	4
Figura 2- Localização da Bacia sedimentar do Amazonas. Fonte: Cunha (2000).	5
Figura 3- Carta cronoestratigráfica da Bacia do Amazonas, recortada o intervalo entre Pré-Cambriano ao Paleozoico, com destaque para o período Devoniano. Fonte: Modificado de Cunha <i>et al.</i> (2007).	6
Figura 4- Perfil composto da seção analisada. Fonte: Corrêa (2020).....	11
Figura 5- Plano de simetria dos braquiópodes e moluscos bivalves. Fonte: Modificado de Williams <i>et al.</i> (1997).	15
Figura 6- Formatos das conchas levando em consideração o posicionamento do protegulum. Fonte: Williams <i>et al.</i> (2007).....	16
Figura 7- Características morfológicas descritivas das valvas dos braquiópodes. A) Características gerais, B) Formato das valvas e C) Ornamentação. Fonte: Mateus (2017).	17
Figura 8- Microestruturas das valvas de braquiópodes. A) Pontuadas, B) Pseudopontuada e C) Impontuada. Fonte: (Prothero 2013).....	18
Figura 9- Características morfológicas descritivas das valvas de braquiópodes: A) Comissura e B) Perfis laterais. Fonte: Mateus (2017).....	19
Figura 10- A) Morfologia do Pedículo. B) e C) Exemplos raros da preservação do pedículo em braquiópodes cambrianos da China. Fonte: A) Carlson (2016); B) e C) Zhang <i>et al.</i> (2005).....	20
Figura 11- Musculatura dos braquiópodes. A) disposição dos músculos em alguns rhynchonelliformes e B) disposição dos músculos em alguns linguliformes. Fonte: (Williams <i>et al.</i> 2007).	21
Figura 12- Cavidade do celoma e manto em braquiópodes. Fonte: Williams <i>et al.</i> (1997).	22
Figura 13- Diversidade de gêneros ao longo do Fanerozoico. Fonte: Carlson (2016).....	24

Figura 14-Localização das províncias paleobiogeográficas “Boreal” ao norte e “Austral” ao sul e do hipotético continente “Falklandia”, reconhecidos por Clarke (1913). Fonte do mapa: Penn-Clarke (2019).....	29
Figura 15- Distribuição de reinos e províncias paleobiogeográficas, com base nas distribuições de táxons endêmicos de braquiópodes, proposta por Boucot <i>et al.</i> (1969). Fonte do mapa: Penn-Clarke (2019).....	30
Figura 16- Paleobiogeografia do período Devoniano com base em Boucot (1988), Torsvik & Cocks (2011, 2013) e Boucot <i>et al.</i> (2013). Fonte do mapa: Penn-Clarke & Harper (2020).....	31
Figura 17- A) áreas biogeográficas ao longo do Devoniano; B) número de gêneros de braquiópodes ao longo do Devoniano. Fonte: A) Penn-Clarke & Harper (2020); B) Williams <i>et al.</i> (2007).	32
Figura 18- Biorregiões do Oeste de Gondwana durante o intervalo Praguiano-Eifeliano baseada na distribuição das faunas de braquiópodes. Fonte: Penn-Clarke & Harper (2020).....	34
Figure 19- Location of the study area. Source: author.	43
Figure 20- Composed stratigraphic section of the analyzed sample site. Source: author.	46
Figure 21- A – D: <i>Orbiculoidea baini</i> – A) MPEG- 3660 (ventral valve, internal mould), B) MPEG- 3660 (detail of the pedicle track), C) MPEG- 3657 (ventral valve, internal mould), and D) MPEG- 3662 (ventral valve, internal mould). E – F: <i>Orbiculoidea bodenbenderi</i> – E) MPEG-3668 (ventral valve, external mould) and F) MPEG-3668 (detail of the rugellae in posterior margin). G – L: <i>Orbiculoidea excentrica</i> – G) MPEG- 3689 (dorsal valve, external mould), H) MPEG-3690 (dorsal valve, counter mold of MPEG-C9P1-4A), I) MPEG-3686 (dorsal valve, internal mould), J) MPEG-3672 (dorsal valve, internal mould), K) MPEG-3719 (ventral valve, internal mould), and L) MPEG-3720 (ventral valve, internal mould). Scale bar: 2 mm.	52

- Figure 22- A – D: *Orbiculoidea xinguensis* sp. nov. – A) MPEG-3729 (dorsal valve, external mould), B) MPEG-3723 (dorsal valve, external mould), C) MPEG-3735 (dorsal valve, external mould), D) MPEG-3740 (ventral valve, internal mould), and E) MPEG-3740 (detail of the pedicle track). F – I: *Orbiculoidea katzeri* sp. nov. – F) MPEG-3746 (dorsal valve, internal mould), G) MPEG-3759 (dorsal valve, external mould), H) MPEG-3758 (dorsal valve, external mould), and I) B) MPEG-3760 (ventral valve, internal mould). Scale bar: A), B), C), D), F), G), H), and I): 2mm; E): 1mm.55
- Figure 23- SEM images. A – D: *Orbiculoidea xinguensis* sp. nov. – A) MPEG-3726 (dorsal valve, external mould), B) MPEG-3726 (rugellae well-marked, with regular interspaces), C) MPEG-3728 (dorsal valve, external mould), and D) MPEG-3728 (absence of micro-ornamentation). E – F: *Orbiculoidea katzeri* sp. nov. – E) MPEG-3746 (dorsal valve, internal mould) and F) MPEG-3746 (absence of micro-ornamentation).56
- Figure 24- Geographic distribution of *Orbiculoidea baini*, *Orbiculoidea bodenbenderi*, and *Orbiculoidea excentrica*. Source: author.59
- Figure 25- A) Gondwana 445 Ma paleogeographic arrangement. I) Amazonas Basin; II) Parnaiba Basin; III Parana Basin. B) Distribution of the *Orbiculoidea* genus during the Silurian (430 Ma); black numbers and circles represent the number of occurrences. Source: A) modified from Torsvik & Cocks (2013); B) modified from Zhang *et al.* (2018).60
- Figure 26- A) Gondwana 400 Ma paleogeographic arrangement. I) Amazonas Basin; II) Parnaiba Basin; III Parana Basin. B) Distribution of the *Orbiculoidea* genus during the Lower Devonian (400 Ma); black numbers and circles represent the number of occurrences. Source: A) modified from Torsvik & Cocks (2013); B) modified from Zhang *et al.* (2018).61
- Figure 27- Location of the Amazonas Basin; b) Cronostratigraphic chart of the Amazonas Basin, highlighting the Trombetas Group. Source: a) Cunha (2000); b) Cunha *et al.* (2007).72
- Figure 28- The study area location.73
- Figure 29- Composed stratigraphic section. Source: Corrêa & Ramos (2021).74

- Figure 30- Scatter diagram plotting length to width of *Schellwienella amazonensis* n. sp. from Amazonas Basin, Brazil..... 76
- Figure 31- *Schellwienella amazonensis* n. sp., external ventral valves. A) MPEG-3838-I mold; B) MPEG-3827-Ia mold; C) MPEG-3780-Ia mold; D) MPEG-3818-I mold; E) MPEG-3816-Ia countermold; F) MPEG-3802-Ic mold; G) MPEG-3762-Id mold; H) MPEG-3830-Ia mold; I) MPEG-4157-Ib mold; J) MPEG-3790-I mold; K) MPEG-3799-Ia mold; L) MPEG-3832-I mold; M) MPEG-3814-I mold; N) MPEG-3795-Ia countermold; O) MPEG-3785-I mold. Scale bar: 2 mm. 78
- Figure 32- *Schellwienella amazonensis* n. sp., external dorsal valves. A) MPEG-3780-Ic mold; B) MPEG-3860-I mold; C) MPEG-3863-I mold; D) MPEG-3817-d countermold; E) MPEG-3855-Ia mold; F) MPEG-3855-Ib mold; G) MPEG-3851-I countermold; H) MPEG-3803-Ib countermold; I) MPEG-3856-I mold; J) MPEG-3870-I mold; K) MPEG-3827-Ib countermold; L) MPEG-3874-I countermold; M) MPEG-3769-Ib countermold; N) MPEG-3872-I countermold; O) MPEG-3829-Ic mold. Scale bar: 2 mm. 79
- Figure 33- *Schellwienella amazonensis* n. sp., internal ventral valves. A) MPEG-3812-Ia mold; B) MPEG-3784-I mold; C) MPEG-3762-Ic mold; D) and E) countermold of MPEG-3762-Ic II; F) MPEG-3834-I mold; G) MPEG-3808-Ia mold; H) MPEG-3820-I mold; I) MPEG-3807-Ia mold; J) MPEG-3779-I mold; K) MPEG-3831-Ib mold; L) MPEG-3773-I mold; M) MPEG-3817-Ia mold; N) MPEG-3819-I mold; O) MPEG-3817-Ic mold. Scale bar: 2 mm. 80
- Figure 34- *Schellwienella amazonensis* n. sp., internal dorsal valves. A) MPEG-3793-Ic countermold; B) MPEG-3873-Ib mold; C) MPEG-3842-I countermold; D) MPEG-3841-I mold; E) MPEG-3862-I mold; F) MPEG-3843-I mold; G) MPEG-3840-Ib mold; H) MPEG-3854-I mold; I) MPEG-3807-Ib mold; J) MPEG-3793-Ib countermold; K) MPEG-3852-I countermold; L) MPEG-3855-Ic countermold. Scale bar: 2 mm. 81
- Figure 35- Morphological details of *Schellwienella amazonenses* n. sp., A) MPEG-3762-Ic internal ventral countermold; B) MPEG-3820-I internal ventral mold; C) and D) MPEG-3808-Ia internal ventral mold; E) MPEG-3802-Ib external ventral countermold; F) MPEG-3816-Ia external ventral mold. 82

- Figure 36- *Schuchertella agassizi* from Maecuru and Ererê formations. A) MPEG-0830-I external ventral mold; B) MPEG-0159-I external ventral mold; C) MPEG-0159-II external ventral mold; D) MPEG-029-I external ventral mold; E) MPEG-029-I ornamentation deltails; F) MPEG-159-III external dorsal mold; G) MPEG-026-I external dorsal countermold; H) MPEG-0214-I internal dorsal countermold; I) MPGE-053-I internal dorsal countermold. Maecuru Formation: MPEG-029-I, MPEG-026-I, and MPGE-053-I; Ererê Formation MPEG-0830-I, MPEG-0159-I, MPEG-0159-II, MPEG-159-III, and MPEG-0214-I. Scale bar: 2 mm..... 87
- Figure 37- Distribution of the *Schellwienella* throughout the Devonian. Base map modified from Scotese *et al.* (1999), Boucot *et al.* (2013), Videira-Santos & Scheffler (2024). 89
- Figure 38- Distribution of the *Schellwienella* throughout the Carboniferous. Base map modified from Scotese (2004), Metcalfe (2011), and Shi *et al.* (2016). Ocean surface circulation patterns modified from Smith & Read (2000), Hüneke (2006), and Shi *et al.* (2016). 91
- Figure 39- A) Location of the Amazonas Basin (Cunha 2000); B) Stratigraphic chart of the Amazonas Basin (Cunha *et al.* 2007), highlighting the Devonian. 102
- Figure 40- Expeditions in the Amazonas basin. 104
- Figure 41- A) and B) Sampling sites of the Maecuru (OAD3, OAD4, and OAD4A) and Ererê (OAD6 and OAD22) formations marked during the Orville Adalbert Derby Expedition (Fonseca 2004). C) and D) Sampling sites of the Manacapuru Formation (Corrêa & Ramos 2021). 106
- Figure 42- Brachiopods collected during the Program of paleontological salvage of the Belo Monte hydroelectric power plant construction and stored in the paleontological collection from Museu Paraense Emílio Goeldi. Rhynchonellata: A) MPEG-4155-I, B) MPEG-4156-I and C) MPEG-4157-I; Lingulata: D) MPEG-3660-I, E) MPEG-3686-I and F) MPEG-4154-I. Scale bar: 2mm. Source: A) – C) and F) author; D) – E) Corrêa & Ramos (2021). 107

- Figure 43- Brachiopod-based bioregions of West Gondwana during the Pragian–Eifelian (Penn-Clarke & Harper 2020). Abbreviations: Ac—Accraian (Ghana), Am—Amazonas (Brazil), Bo—Bové (Guinea, Guinea-Bissau, Senegal), Ca—Cape (South Africa), Ch—Chaco (Bolivia), FB—Fox Bay (Falkland Islands), Ll—Llanos (Colombia and Venezuela), NS—“North Saharan” (Tindouf, Ghadamis, Polignac, Murzuq basins), Pa Paraná (Brazil, Paraguay, Uruguay), Px—Parecis (Brazil), Pr—Precordillera (western Argentina), Pn Parnaíba (Brazil), SP—southern Peru, SS—“South Saharan” (Tamesna and Taoudeni basins and Adrar, Hodh regions), Su— Suwannee (Florida, Georgia, United States), Ve—Ventana (eastern Argentina), WA—West Antarctica (“Ellsworth-Whitmore Mountains”), Zo—Zorritas (northern Chile)..... 111
- Figure 44- A) Distribution of the number of brachiopod genera in the Devonian of the Amazonas Basin. B) Global distribution of the number of brachiopod genera in the Devonian (Williams *et al.* 2007). 113
- Figure 45- Paleobiogeographic arrangement of Gondwana 445 Ma. (Torsvik & Cocks 2013). 114
- Figure 46- A) Global eustatic sea level variation in the Devonian (Ross & Ross 1988); B) global ocean average temperature from 500 to 200 Ma. (Wallmann 2004); C) Stratigraphy of the Devonian period in the Amazonas Basin (Cunha *et al.* 2007)..... 116
- Figure 47- Brachiopod diversity (class, order, and genus) recorded in the Devonian units from the Amazonas Basin. 117
- Figure 48- A) paleogeography at 410 Ma. (Torsvik & Cocks 2016); B) Gondwana at 400 Ma. and C) Gondwana at 370 Ma. (Torsvik & Cocks 2013)..... 118

LISTA DE TABELAS

Tabela 1- Sistemática do filo Brachiopoda.....	23
Tabela 2- Principais características que diferenciam os subfilos de braquiópodes.....	28
Tabela 3- Lista de braquiópodes devonianos da Bacia do Amazonas.....	35

SUMÁRIO

DEDICATÓRIA	iv
AGRADECIMENTOS	v
EPIGRAFE	vi
RESUMO	vii
ABSTRACT	ix
LISTA DE ILUSTRAÇÕES	xi
LISTA DE TABELAS	xvii
CAPÍTULO 1 CONSIDERAÇÕES INICIAIS	1
1.1 ESTRUTURA DA TESE	1
1.2 INTRODUÇÃO	1
1.3 PROBLEMÁTICA E JUSTIFICATIVA	2
1.4 OBJETIVO	3
1.5 LOCALIZAÇÃO DA ÁREA DE ESTUDO	4
CAPÍTULO 2 CONTEXTO GEOLÓGICO	5
2.1 SEQUÊNCIA ORDOVÍCIO-DEVONIANA	7
2.2 SEQUÊNCIA DEVONIANA-TOURNASIANA.....	9
CAPÍTULO 3 MATERIAIS E MÉTODOS	10
3.1 MATERIAL.....	10
3.2 MÉTODOS	12
3.2.1 Pesquisa bibliográfica.....	12
3.2.2 Consulta em acervos.....	12
3.2.3 Triagem, preparação e medidas das amostras.....	13
3.2.4 Aquisição e tratamento das imagens.....	13
3.2.5 Identificação taxonômica	14

3.2.6 Catalogação das amostras.....	14
CAPÍTULO 4 FUNDAMENTAÇÃO TEÓRICA.....	15
4.1 PHYLUM BRACHIOPODA.....	15
4.1.1 Morfologia / anatomia.....	16
4.1.2 Classificação.....	22
4.2 PALEOBIOGEOGRAFIA DO DEVONIANO.....	28
4.3 BRAQUIÓPODES DEVONIANOS DA BACIA DO AMAZONAS.....	34
4.3.1 Braquiópodes na Formação Manacapuru.....	37
4.3.2 Braquiópodes na Formação Maecuru.....	37
4.3.3 Braquiópodes na Formação Ererê.....	39
4.3.4 Braquiópodes na Formação Barreirinha.....	39
CAPÍTULO 5 DISCINOIDS (BRACHIOPODA: LINGULATA) FROM THE UPPER MANACAPURU FORMATION (EARLY DEVONIAN), SOUTH BORDER OF AMAZONAS BASIN, BRAZIL.....	41
5.1 INTRODUCTION.....	42
5.2 MATERIAL AND METHODS.....	43
5.3 GEOLOGICAL SETTING.....	44
5.4 RESULTS.....	45
5.4.1 Systematic paleontology.....	47
5.5 DISCUSSION.....	57
5.5.1 Paleoecological aspects.....	57
5.5.2 Stratigraphic and paleobiogeographic distribution.....	58
5.6 CONCLUSIONS.....	63

CAPÍTULO 6	<i>SCHELLWIENELLA AMAZONENSIS</i> NEW SPECIES (ORTHOTETIDA, BRACHIOPODA): THE FIRST RECORD OF THE GENUS FROM THE DEVONIAN OF THE AMAZONAS BASIN (MANACAPURU FORMATION – LOCHKOVIAN), NORTH BRAZIL	69
6.1	INTRODUCTION	70
6.2	GEOLOGICAL SETTING	71
6.3	MATERIAL AND METHODS	73
6.4	RESULTS	75
6.4.1	Systematic paleontology	75
6.5	PALEOBIOGEOGRAPHIC CONSIDERATIONS	87
6.6	CONCLUSION	91
CAPÍTULO 7	RELATIONSHIPS BETWEEN BRACHIOPOD FAUNA (LOCHKOVIAN–FRASNIAN) FROM NORTHWEST GONDWANA (AMAZONAS BASIN) AND ENVIRONMENTAL CHANGES DURING THE DEVONIAN	100
7.1	INTRODUCTION	101
7.2	DATA AND METHODS	103
7.3	MAJOR SCIENTIFIC EXPEDITIONS IN THE DEVONIAN OF THE AMAZONAS BASIN	104
7.4	DEVONIAN BRACHIOPODS FROM THE AMAZONAS BASIN DEPOSITED IN MUSEUMS AND UNIVERSITIES	106
7.5	THE DEVONIAN BRACHIOPODS FROM THE AMAZONAS BASIN	108
7.5.1	Manacapuru Formation (Lochkovian)	108
7.5.2	Maecuru Formation (early Eifelian)	108
7.5.3	Ererê Formation (late Eifelian)	110
7.5.4	Barreirinha Formation (early Frasnian)	112
7.6	RESULTS AND DISCUSSIONS	112

7.7 CONCLUSIONS	119
CAPÍTULO 8 CONSIDERAÇÕES FINAIS.....	126
REFERÊNCIAS.....	128
APÊNDICE A - MATERIAL SUPLEMENTAR DO CAPÍTULO 6, SCHELLWIENELLA AMAZONENSIS NEW SPECIES (ORTHOTETIDA, BRACHIOPODA): THE FIRST RECORD OF THE GENUS FROM THE DEVONIAN OF THE AMAZONAS BASIN (MANACAPURU FORMATION – LOCHKOVIAN), NORTH BRAZIL.....	138
ANEXO A - MATERIAL SUPLEMENTAR DO CAPÍTULO 7, RELATIONSHIPS BETWEEN BRACHIOPOD FAUNA (LOCHKOVIAN–FRASNIAN) FROM NORTHWEST GONDWANA (AMAZONAS BASIN) AND ENVIRONMENTAL CHANGES DURING THE DEVONIAN	144

CAPÍTULO 1 CONSIDERAÇÕES INICIAIS

1.1 ESTRUTURA DA TESE

A presente tese está organizada em oito capítulos, sendo três em formato de artigos. O capítulo 1 corresponde à parte introdutória que inclui: estrutura da tese, introdução, problemática, justificativa, objetivos e localização da área de estudo. No capítulo 2 é apresentado os aspectos geológicos da área de estudo; no capítulo 3 são apresentados os materiais e métodos utilizados nesta tese; no capítulo 4 contém a fundamentação teórica e os resultados estão apresentados na forma de três artigos científicos.

O primeiro artigo (capítulo 5), denominado “Discinoids (Brachiopoda: Lingulata) from the Upper Manacapuru Formation (Early Devonian), south border of Amazonas Basin, Brazil”, foi publicado no periódico *Journal of South American Earth Sciences*, 105 (2021): 111803 (Corrêa & Ramos 2021), apresenta resultados taxonômicos de braquiópodes *Orbiculoidea*, além de discussões quanto a distribuição paleobiogeográfica deste gênero.

No segundo artigo (capítulo 6), com título “*Schellwienella amazonensis* new species (Orthotetida, Brachiopoda): the first record of the genus from the Devonian of the Amazonas Basin (Manacapuru Formation – Lochkovian), North Brazil”, é realizada a identificação de uma nova espécie de *Schellwienella*, sendo este o primeiro registro do gênero para a Bacia do Amazonas, além de ser discutida a distribuição deste gênero ao longo do Devoniano e Carbonífero. Este artigo foi submetido ao periódico *Journal of South American Earth Sciences*.

O terceiro artigo (capítulo 7), intitulado “Relationships between brachiopod fauna (Lochkovian–Frasnian) from northwest Gondwana (Amazonas Basin) and environmental changes during the Devonian” publicado no periódico *Palaeogeography, Palaeoclimatology, Palaeoecology*, 629 (2023):111803 (Corrêa & Ramos 2023), é realizado um levantamento da fauna de braquiópodes devonianos da Bacia do Amazonas e discutido a relação com as mudanças ambientais que ocorrem durante este período.

1.2 INTRODUÇÃO

O filo Brachiopoda Duméril, 1806 é representado por macroinvertebrados que tiveram sua primeira ocorrência no Cambriano, estendendo-se até os dias atuais, e apresentam grande abundância nos depósitos marinhos do Paleozoico inferior (Williams *et al.* 1997, 2007). Esses organismos são amplamente utilizados em estudos paleoambientais, paleobiogeográficos e na detecção de eventos de extinções (Bosetti *et al.* 2010, Zabini *et al.* 2010, Zabini & Bosetti 2011,

Zabini *et al.* 2012 a, b, Comniskey *et al.* 2016, Comniskey & Bosetti 2017, Penn-Clarke & Harper 2020, Ribeiro *et al.* 2024 a, b).

No decorrer do Ordoviciano, mudanças na configuração das massas continentais e nas condições climáticas colaboraram para a Glaciação Hirnantiana (Ordovício-Siluriano), que persistiu por quase 35 milhões de anos (Finnegan *et al.* 2011). Neste período Gondwana estava centrado sobre o Polo Sul. As condições climáticas subpolares em Gondwana eram bastante extremas, dificultando o desenvolvimento de faunas ricas em diversidade de braquiópodes. No decorrer do Siluriano houve derretimento de parte das calotas polares do Norte da África e na América do Sul, resultando em transgressões marinhas que alcançaram grande parte do território do supercontinente Gondwana (Ludwig 1964, Carozzi *et al.* 1973, Caputo 1984, Caputo & Crowell 1985, Grahn & Caputo 1992, Cunha *et al.* 1994). Desta forma surgiram os mares rasos, durante a transição do Siluro-Devoniano, no noroeste de Gondwana (Bolívia, Brasil, África do Sul e Austrália) com temperaturas amenas, fundamentais para a radiação dos braquiópodes no Devoniano.

Apesar dessa grande radiação durante o Devoniano, os registros deste grupo são raros no Devoniano Inferior da Bacia do Amazonas (formações Manacapuru e Jatapu). Já o Devoniano Médio é marcado por abranger a maior diversidade de braquiópodes devonianos do Brasil, procedentes dos estratos das formações Maecuru e Ererê, cujas pesquisas se iniciaram no final do século XIX, com as “Expedições Morgan” e a “Comissão Geológica do Império do Brasil” (Carvalho 1975, Fonseca 2004, Ponciano *et al.* 2007, Fonseca & Ponciano 2011).

1.3 PROBLEMÁTICA E JUSTIFICATIVA

Durante o Devoniano, o filo atingiu seu pico de diversidade e sofreu o seu segundo maior declínio, ficando atrás apenas do evento de extinção em massa Permo-Triássica. Este foi um período importante para o filo Brachiopoda, marcado pelo ápice global em sua diversidade e pelo seu segundo maior declínio (Williams *et al.* 2007); ainda, a biorregionalização ganhou maior evidência, chegando ao seu nível máximo de expansão durante o Emsiano, mesma idade em que é registrado o maior número de gêneros de braquiópodes do Paleozoico (Boucot *et al.* 1969, Johnson *et al.* 1973, Boucot 1988, Boucot & Blodgett 2001, Dowding & Ebach 2018). Coincidentemente, as áreas biogeográficas foram reduzindo e entrando em colapso à medida que o número de gêneros de braquiópodes foi diminuindo ao longo do Eifeliano, Givetiano e Frasniano (Dowding & Ebach 2018, 2019, Penn-Clarke 2019, Penn-Clarke & Harper 2020). Vale ressaltar que durante o Devoniano a Bacia do Amazonas estava situada em uma região

importante, fronteira entre os reinos Malvinocáfrico e Américas Orientais (Boucot 1988, Melo 1988, Boucot *et al.* 2001).

Dentre as bacias sedimentares paleozoicas brasileiras, a Bacia do Amazonas é a que possui a maior diversidade de braquiópodes do Devoniano, com registros nas formações Manacapuru (Lochkoviano), Maecuru (Eoeifeliano), Ererê (Neoeifeliano) e Barreirinha (Eofrasniano) (Rathbun 1874, 1878, Clarke 1899, 1913, Katzer 1903, 1933, Carvalho 1972, 1975, Copper 1977, Macambira *et al.* 1977, Melo 1985, Grahn & Melo 1990, Fonseca 2004, Fonseca & Ponciano 2011, Tomassi *et al.* 2015, Corrêa 2020). A Formação Manacapuru possui uma fauna de braquiópodes pouco conhecida, cujos trabalhos taxonômicos começaram recentemente, graças a uma rica assembleia fossilífera, que foi recuperada durante o Programa de Salvamento do Patrimônio Paleontológico da Usina Hidrelétrica de Belo Monte, no município de Vitória do Xingu, estado do Pará, os quais se encontram depositados no Acervo Paleontológico da Coordenação de Ciências da Terra e Ecologia do Museu Paraense Emílio Goeldi, Belém, Pará (Tomassi *et al.* 2015).

Estudos taxonômicos realizados nestas amostras permitiram o registro de braquiópodes da família Discinidae, e a identificação de três espécies novas para a Formação Manacapuru, *Orbiculoidea baini*, *Orbiculoidea bodenbenderi* e *Orbiculoidea excentrica*, além de *Orbiculoidea* sp. 1, *Orbiculoidea* sp. 2 e *Gigadiscina?* sp. (Corrêa 2020). Estes são os registros mais antigos de *Orbiculoidea* na América do Sul, o que foi explicado devido a dois principais pontos: a proximidade dos blocos continentais Laurússia e Gondwana na transição do Siluro-Devoniano e por fatores ambientais, como condições marinhas rasas na Bacia do Amazonas, no Lockoviano, favorecendo a instalação desses organismos (Corrêa 2020).

Desta forma, dar continuidade a identificação da fauna de braquiópodes da Formação Manacapuru é de fundamental importância, incluindo assim, a Bacia do Amazonas nas discussões paleobiogeográficas durante o Lochkoviano, além de proporcionar um registro estratigráfico mais completo desse grupo no Devoniano da Bacia do Amazonas, uma vez que já estão bem conhecidos nas formações Maecuru, Ererê e Barreirinha.

1.4 OBJETIVO

Esta tese visa o estudo taxonômico de braquiópodes da Formação Manacapuru, borda sul da Bacia do Amazonas (Município de Vitória do Xingu-PA), além de analisar e discutir os possíveis fatores que influenciaram a radiação dos gêneros de braquiópodes entre as unidades sedimentares da Bacia do Amazonas (formações Manacapuru, Maecuru, Ererê e Barreirinha).

Como objetivos específicos:

- Identificar gêneros e espécies de braquiópodes da Formação Manacapuru, Bacia do Amazonas;
- Realizar o levantamento das ocorrências paleobiogeográficas da fauna identificada;
- Verificar a similaridade da fauna identificada com a de outras unidades sedimentares devonianas da Bacia do Amazonas e demais bacias paleozoicas;
- Discutir e analisar as possíveis mudanças ambientais que influenciaram na distribuição dos braquiópodes devonianos da Bacia do Amazonas.

1.5 LOCALIZAÇÃO DA ÁREA DE ESTUDO

A área de estudo (Figura 1) compreende quatro pontos de coleta: C3P1, C9P1, C13P1 e C14P1, situados na região de influência da construção da Usina Hidrelétrica de Belo Monte, no município de Vitória do Xingu, sudoeste do Pará, norte do Brasil. Do aeroporto de Altamira até a área de estudo são percorridos aproximadamente 62,5 km, pela rodovia BR-230. É limitada ao norte pelo município de Porto de Moz, a leste por Anapu, ao sul pela cidade de Senador José Porfírio e a oeste pelo município de Altamira.

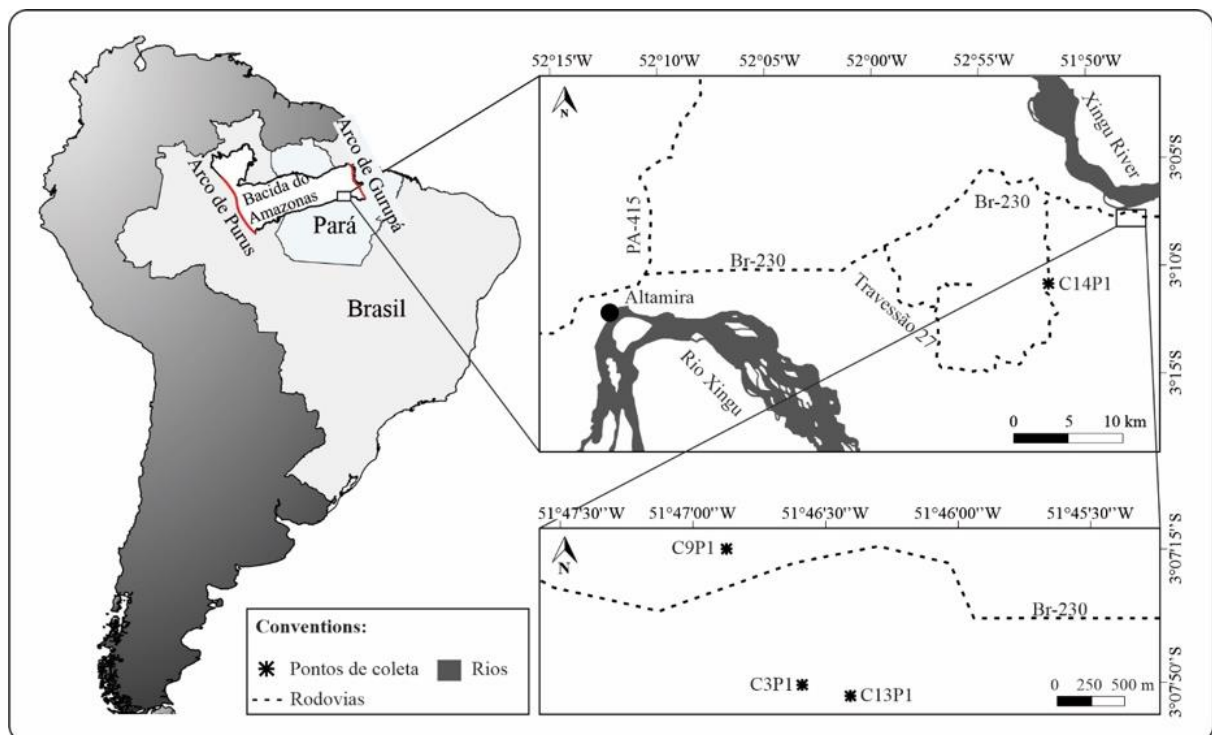


Figura 1- Mapa de localização da área estudada. Fonte: Corrêa (2020).

CAPÍTULO 2 CONTEXTO GEOLÓGICO

A Bacia Paleozoica do Amazonas (Figura 2) abrange uma área de aproximadamente 500.000 km² distribuída em três estados ao norte do Brasil: Amapá, Amazonas e Pará (Cunha *et al.* 1994). Classificada como intracratônica do “Tipo I - Interior Simples”, tem seus limites demarcados ao norte pelo Escudo das Guianas, ao sul pelo Escudo Brasileiro, a leste pelo Arco de Gurupá e a oeste pelo Arco de Purus (Cunha *et al.* 1994, Klemme 1980).

A bacia se formou sobre o embasamento cristalino denominado Cráton Amazônico (Brito Neves & Almeida 2003). O cráton foi formado a partir de eventos de acreção de arcos magmáticos e faixas móveis durante o Paleoproterozoico e Mesoproterozoico, em volta de um núcleo mais antigo, de idade arqueana (Cordani *et al.* 1979, Cordani & Brito Neves 1982, Tassinari 1996, Tassinari *et al.* 2000, Tassinari & Macambira 1999, 2004, Santos *et al.* 2000, 2006). O modelo de compartimentação tectônica/geocronológica do Cráton Amazônico é composto por seis províncias: Amazônia Central (2,5 Ga), Maroni-Itacaiúnas (2,2 – 1,9 Ga), Ventuari-Tapajós (1,9 – 1,8 Ga), Rio Negro – Juruena (1,8 – 1,55 Ga), Rondoniana-San Ignácio (1,55 – 1,3 Ga) e Sunsás (1,25 – 1,0 Ga) (Tassinari & Macambira 1999).

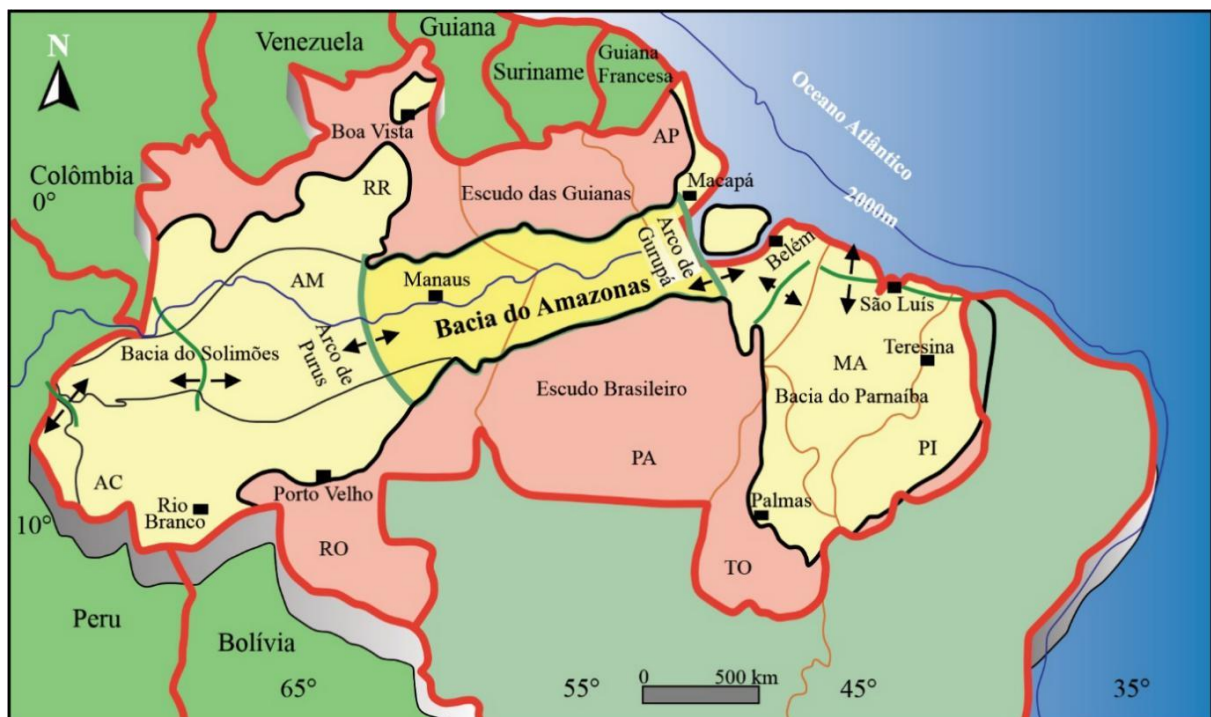


Figura 2- Localização da Bacia sedimentar do Amazonas. Fonte: Cunha (2000).

Uma das hipóteses que explica a origem da Bacia do Amazonas é de que a mesma estaria associada à dispersão de esforços de direção norte-sul, referente ao processo de fechamento do Ciclo Brasileiro (Cunha *et al.* 2007). Posteriormente aos processos distensivos, ocorreu o

resfriamento dos corpos magmáticos, dando início à subsidência térmica regional e surgimento de uma sinéclise intracontinental, que resultou em uma bacia de geometria alongada e de preenchimento predominante de rochas siliciclásticas (Figura 3), essencialmente paleozoicas, intrudidas no Mesozoico por diques e soleiras de diabásio (Almeida 1967, Caputo 1984, Cunha *et al.* 2007).

O arcabouço estratigráfico pode atingir uma espessura de aproximadamente 5.000 m, e é dividido em duas megassequências de primeira ordem, uma Paleozoica e outra Mesozoica (Caputo 1984, Cunha *et al.* 2007). A megassequência paleozoica é formada por rochas sedimentares provenientes de diversas naturezas (plataforma rasa, plataforma distal, deltaico, fluvial, flúvio-deltaico, lacustre e glacial) e ligadas a grandes intrusões de diques e soleiras de diabásio (Cunha *et al.* 2007, Matsuda *et al.* 2010). Ela é dividida em outras três sequências de segunda ordem: Sequência Ordovício-Devoniana, Devoniana-Tournasiana e Pensilvaniano-Permiana (Cunha *et al.* 2007, Matsuda *et al.* 2010).

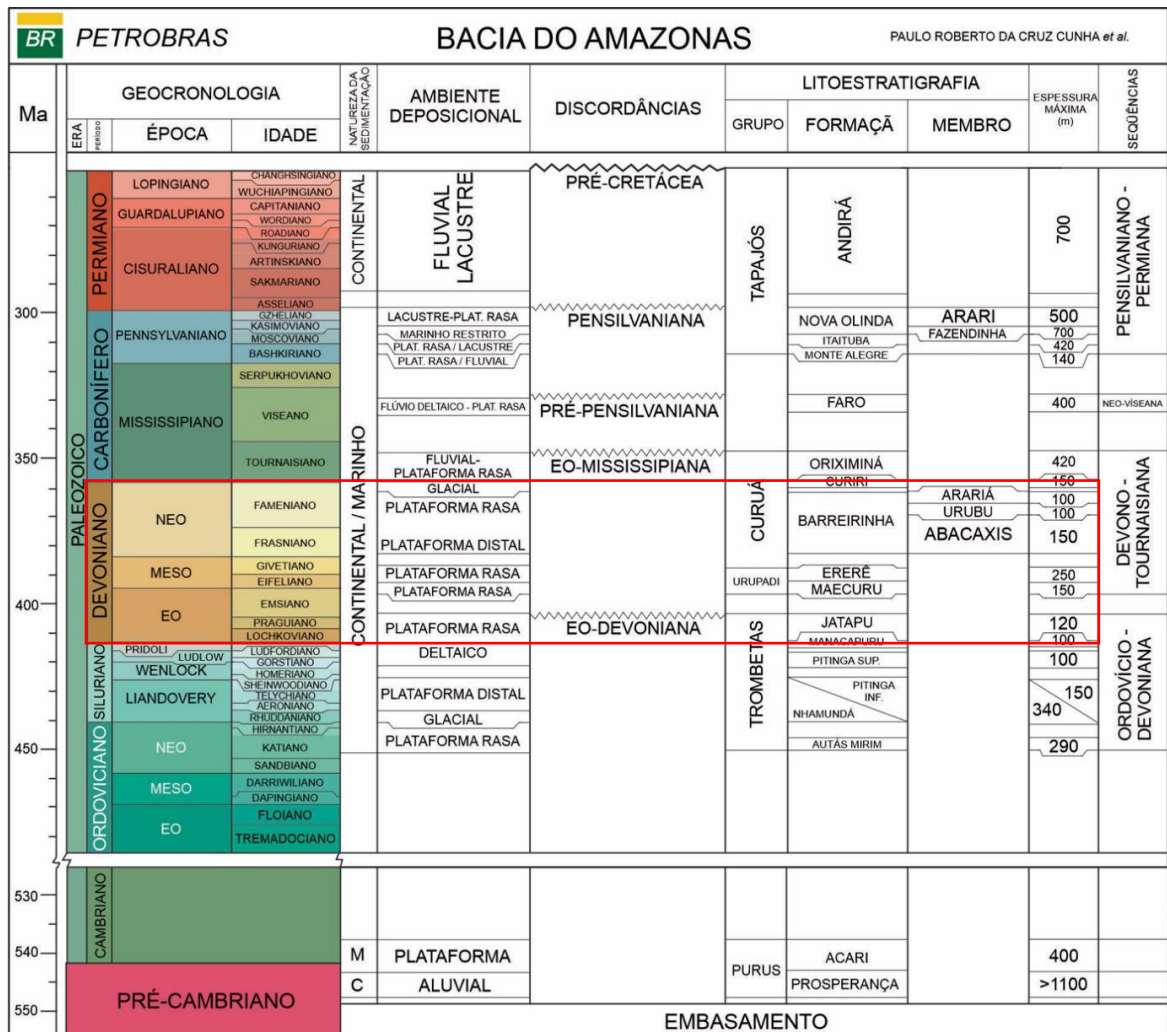


Figura 3- Carta cronoestratigráfica da Bacia do Amazonas, recortada o intervalo entre Pré-Cambriano ao Paleozoico, com destaque para o período Devoniano. Fonte: Modificado de Cunha *et al.* (2007).

2.1 SEQUÊNCIA ORDOVÍCIO-DEVONIANA

A Sequência Ordovício-Devoniana registra a fase inicial de deposição na sinéclise intracontinental da Bacia do Amazonas e é caracterizada por pulsos transgressivos-regressivos (Cunha *et al.* 1994). O arcabouço estratigráfico que compõe esta sequência é denominado Grupo Tombretas (Ludwig 1964), cuja sedimentação é resultado da alternância entre ambientes glaciais e marinhos, situados em *onlap* sobre o Arco de Purus na faixa mais a oeste da bacia; o topo do grupo é marcado por uma intensa erosão resultante da Orogenia Famatiniana (Zalán 1991), ou Caledoniana, e vasto rebaixamento do nível do mar (Cunha 1994); já na porção a leste, a sedimentação ultrapassou o Arco de Gurupá (não existente nesse período) favorecendo a ligação com as bacias do noroeste da África (Cunha *et al.* 2007).

O Grupo Trombetas (Ludwig 1964) é composto pelas Formações Autás-Mirim, Nhamundá, Pitinga e Manacapuru (Cunha *et al.* 1994). Posteriormente, Cunha *et al.* (2007) propuseram a entrada de mais uma formação no Grupo Trombetas, a Formação Jatapu, antigo Membro Jatapu, pertencente à Formação Maecuru (Grupo Urupadi).

A Formação Autás-Mirim, situada na parte basal do Grupo Trombetas, é composta de arenitos intercalados por siltitos flúvio-estuarino, de idade Neo-Ordoviciano (Caradoc? - Ashgill), que não afloram na bacia (Caputo *et al.* 1971, Daemon & Contreiras 1971, Caputo 1984, Grahn 2005).

A Formação Nhamundá representa uma sequência transgressiva-regressiva (Caputo 1984, Cunha *et al.* 1994), composta por quartzo-arenitos, folhelhos e diamictitos (Nogueira *et al.* 1999). Caputo (1984) propôs um ambiente deposicional marinho raso, com interferências de tempestades e geleiras, enquanto Grahn (2005), propôs de forma indireta, idade Llandovery-Wenlock para parte superior da unidade.

Já a Formação Pitinga é constituída por folhelhos, arenitos, siltitos e diamictitos e sua deposição está associada a uma transgressão marinha pós-glaciação siluriana (Caputo 1984, Carozzi *et al.* 1973, Cunha *et al.* 2007, Gonçalves *et al.* 2017). Estudos de graptólitos levaram Caputo & Andrade (1968) a sugerir uma idade Eo-Siluriana para essa sequência sedimentar; já, os estudos realizados com quitinozoários por Grahn (2005) indicam uma idade entre Llandovery-Wenlock para a parte inferior da formação, e Ludlow-Pridoli para sua porção superior.

A Formação Manacapuru, de onde provém o material de estudo, foi primeiramente proposta como membro Manacapuru, representando a porção superior da antiga “Formação Trombetas” (Caputo *et al.* 1971). Posteriormente foi elevada hierarquicamente à formação

(Caputo 1984). É caracterizada por arenitos de granulometria fina a média, pelitos neríticos e litorâneos, folhelhos e siltitos laminados, compondo uma sequência transgressiva-regressiva, depositada em ambientes deltaicos e de plataforma rasa (Caputo 1984, Carozzi *et al.* 1973, Cunha *et al.* 1994, Cunha *et al.* 2007, Rocha *et al.* 2019, Souza & Nogueira 2009).

Análises bioestratigráficas efetuadas por Grahn (2005) estabeleceram idade Pridoli–Lochkoviano para a referida formação. Litologicamente, a Formação Manacapuru é correlata às formações Jaicós (Bacia do Parnaíba), Furnas (Bacia do Paraná), Nardouw (África do Sul) e Atafaiata (Bacia do Saara argeliano) (Bennacef *et al.* 1971, Caputo & Lima 1984). O conteúdo fossilífero da Formação Manacapuru abrange braquiópodes, conulários, fragmentos de euripterídeos, icnofósseis, palinomorfos e peixes (Lange 1967, Quadros 1985, Janvier & Melo 1988, Grahn & Melo 1990, Grahn & Paris 1992, Grahn 2005, Wanderley Filho *et al.* 2005, Steemans *et al.* 2008, Rocha *et al.* 2019, Corrêa 2020).

A assembleia fossilífera de braquiópodes estudada é característica de ambiente marinho (Clarkson 1992, Williams *et al.* 2007). Levando em consideração as características litológicas, palinológicas e o conteúdo fossilífero, apresentados por Tomassi *et al.* (2015a) e do Relatório Técnico Final do Programa de Salvamento do Patrimônio Paleontológico da Usina Hidrelétrica de Belo Monte (Tomassi *et al.* 2015b), além dos dados sedimentares e bioestratigráficos do poço SR-17 (localizado na região de Belo Monte) estudado por Grahn & Melo (1990), posicionam-se os afloramentos estudados na porção superior da Formação Manacapuru. De acordo com a literatura, a porção inferior desta unidade é atribuída a um ambiente deltaico, sem ocorrências de macrofósseis, já a porção superior é associada a um ambiente de plataforma rasa (Carozzi *et al.* 1973, Cunha *et al.* 2007, Rocha *et al.* 2019). Com base em dados palinológicos (quitinozoários) realizadas por Grahn (2005) na região de Belo Monte, foram atribuídas idades Pridoli (Siluriano superior) para a parte inferior da Formação Manacapuru, e Lochkoviano (Devoniano Inferior) para a porção superior. Mediante esse fato, infere-se que os afloramentos estudados estão situados na porção marinha da referida formação, a qual corresponde à porção superior, de idade relativa Lochkoviano.

A Formação Jatapu, incluída no Grupo Trombetas por Cunha *et al.* (2007), antigo Membro Jatapu da Formação Maecuru (Grupo Urupadi) (Lange 1967), é constituída por arenitos finos a médios, siltitos e folhelhos micáceos bioturbados, pobre de conteúdo fossilífero, depositados sobre influência marinho raso/transgressivo na base, e depósitos progradacionais deltaicos dominados por marés, na sua parte superior (Cunha *et al.* 2007). Dados palinológicos sugerem idade Lochkoviano- Eoemiano (Melo & Loboziak 2003). Não ocorre descontinuidade temporal significativa entre a base da Formação Jatapu e a parte superior da Formação

Manacapuru (que está subjacente à Formação Jatapu); porém, entre o topo da Formação Jatapu e a base da formação sobreposta, Maecuru, ocorre um hiato temporal / deposicional, evidenciado pela ausência regional das biozonas emsianas AB e FD (Cunha *et al.* 2007). Localmente, na porção basal, ocorrem folhelhos ferruginosos e leitos de hematita e siderita (Cunha 2000).

2.2 SEQUÊNCIA DEVONIANA-TOURNASIANA

A Sequência Devoniana-Tournasiana registra um novo ciclo sedimentar transgressivo-regressivo, representado por condições marinhas com incursões glaciais, situado sobre a discordância decorrente da Orogenia Famatiniana (Caputo 1984, Cunha *et al.* 2007). Essa sequência é representada pelos grupos Urupadi e Curuá.

Segundo Caputo (1984), o Grupo Urupadi é formado pelas formações Maecuru e Ererê. A Formação Maecuru é composta por arenitos e pelitos neríticos a deltaicos, de idade Neoemsiano-Eifeliano (Grahn & Melo 2004, Cunha *et al.* 2007). O conteúdo fossilífero da formação Maecuru abrange bivalves, braquiópodes, briozoários, conulários, corais, crinóides, gastrópodes, trilobitas e tentaculites (Carvalho 1975, Melo 1988, Cunha *et al.* 1994, Ponciano & Machado 2007b, Fonseca & Ponciano 2011, Scheffler *et al.* 2015). A Formação Ererê representa o intervalo Neoeifeliano-Eogivetiano da Bacia do Amazonas e é constituída por siltitos, folhelhos e arenitos de origem deltaicos a neríticos (Cunha *et al.* 2007, Melo & Loboziak 2003). O conteúdo fossilífero da Formação Ererê é composto por braquiópodes, escolecodontes, moluscos, ostracodes, tentaculites e trilobitas (Carvalho 1975, Melo 1988, Cunha *et al.* 1994, Fonseca & Costa 1999, Loboziak & Melo 2002, Fonseca 2004, Fonseca & Ponciano 2011).

O grupo Curuá é constituído pelas formações Barreirinha, Curiri e Oriximiná, depositadas após um pequeno pulso regressivo (Ludwig 1964, Cunha *et al.* 2007). A Formação Barreirinha possui um arcabouço estratigráfico formado por folhelhos cinza escuros a negros (físseis e carbonosos) e siltitos, depositados no contexto marinho anóxico (Loboziak *et al.* 1997, Cunha *et al.* 2007). Litoestratigraficamente é subdividida em três membros Abacaxis, Urubu e Ururiá (Cunha *et al.* 1994, Melo & Loboziak 2003). A Formação Curiri registra o fim do Devoniano na Bacia do Amazonas e é formada por diamictitos, folhelhos e siltitos, depositados em condições glaciais, durante o Famenniano (Caputo 1984, Melo & Loboziak 2003, Cunha *et al.* 2007). A Formação Oriximiná é caracterizada por arenitos finos a médios, com intercalações de siltitos, folhelhos e diamictitos, depositados em ambientes marinho raso/fluviial, durante o intervalo Eotournaisiano-Mesotournaisiano (Caputo 1984, Melo & Loboziak 2003, Cunha *et al.* 2007).

CAPÍTULO 3 MATERIAIS E MÉTODOS

3.1 MATERIAL

O material de estudo é proveniente do projeto “Programa de Salvamento do Patrimônio Paleontológico (PSPP)” da Usina Hidrelétrica de Belo Monte (UHBM), no município de Vitória do Xingu, Estado do Pará, e foi coletado pela equipe TERRAGRAPH PALEONTOLOGIA entre julho de 2011 e outubro de 2015. Geograficamente, a área de estudo (Figura 1) está localizada nas proximidades da Usina Hidrelétrica de Belo Monte, no município de Vitória do Xingu, sudoeste do Pará (Tomassi *et al.* 2015a, b). O acesso à referida área pode ser feito por meio terrestre através da rodovia BR-230, ou por embarcações mediante o Rio Xingu.

As coletas fossilíferas foram realizadas de acordo com os métodos descritos por Tomassi *et al.* (2015). Perfis estratigráficos foram confeccionados, identificando a posição de ocorrência de cada amostra fossilífera. Todas as amostras encontram-se depositadas no acervo paleontológico da Coordenação de Ciências da Terra e Ecologia (COCTE) do Museu Paraense Emílio Goeldi (MPEG), Belém – PA.

As amostras são provenientes de quatro pontos de coleta, C3P1 (9653975 m N, 413823 m L, zona 22M, SAD 69), C9P1 (9655000 m N, 413261 m L, zona 22M, SAD 69), C13P1 (9653898 m N, 414191 m L, zona 22M, SAD 69) e C14P1 (9648213 m N, 406654 m L, zona 22M, SAD 69), que compõem o perfil estratigráfico da área de estudo; os pontos de coletas analisados estão inseridos em estratos da Formação Manacapuru (Tomassi *et al.* 2015).

O perfil composto (Figura 4) é formado da base para o topo, pelo embasamento cristalino, seguido de uma camada de aproximadamente 0,5 metros de arenito maciço de granulometria fina, intercalado por lentes de argila com braquiópodes. Acima, uma camada de arenito de granulometria fina com uma laminação incipiente e braquiópodes dispostos em quase toda a camada. Por fim, um pacote de siltito laminado de aproximadamente 2,1 metros, com braquiópodes ocorrendo concentrados na base desta camada; no topo da camada ocorrem os lingulídeos de forma isolada.

Para o artigo I intitulado “Discinoids (Brachiopoda: Lingulata) from the Upper Manacapuru Formation (Early Devonian), south border of Amazonas Basin, Brazil” foram utilizadas 270 amostras, provenientes dos pontos de coleta C3P1, C9P1, C13P1 e C14P1. Sendo 106 exemplares de discinídeos (MPEG-3655 ao MPEG 3760), e o restante de lingulídeos e rhynchonelliformes.

No artigo II intitulado “*Schellwienella amazonensis* new species (Orthotetida, Brachiopoda): the first and oldest record of the genus from the Devonian of the Amazonas Basin (Manacapuru Formation – Lochkovian), North Brazil”, foram analisadas 178 valvas (MPEG-3761-I ao MPEG-3878-I, MPEG-3886, MPEG-4156-I, MPEG-4157-Ia e MPEG-4157-Ib), provenientes dos pontos de coleta C3P1, C13P1 e C14P1 (Formação Manacapuru). Também examinamos quatro exemplares (MPEG-0018, MPEG-0026, MPEG-0029 e MPEG-0053) de ortotetídeos da Formação Maecuru, coletadas por João Coelho em 1895, e três espécimes (MPEG-0159, MPEG-0214 e MPEG-0830) da Formação Ererê, coletados por Frederich Katzer em 1897, todos armazenados na coleção Paleontológica do Museu Emílio Goeldi.

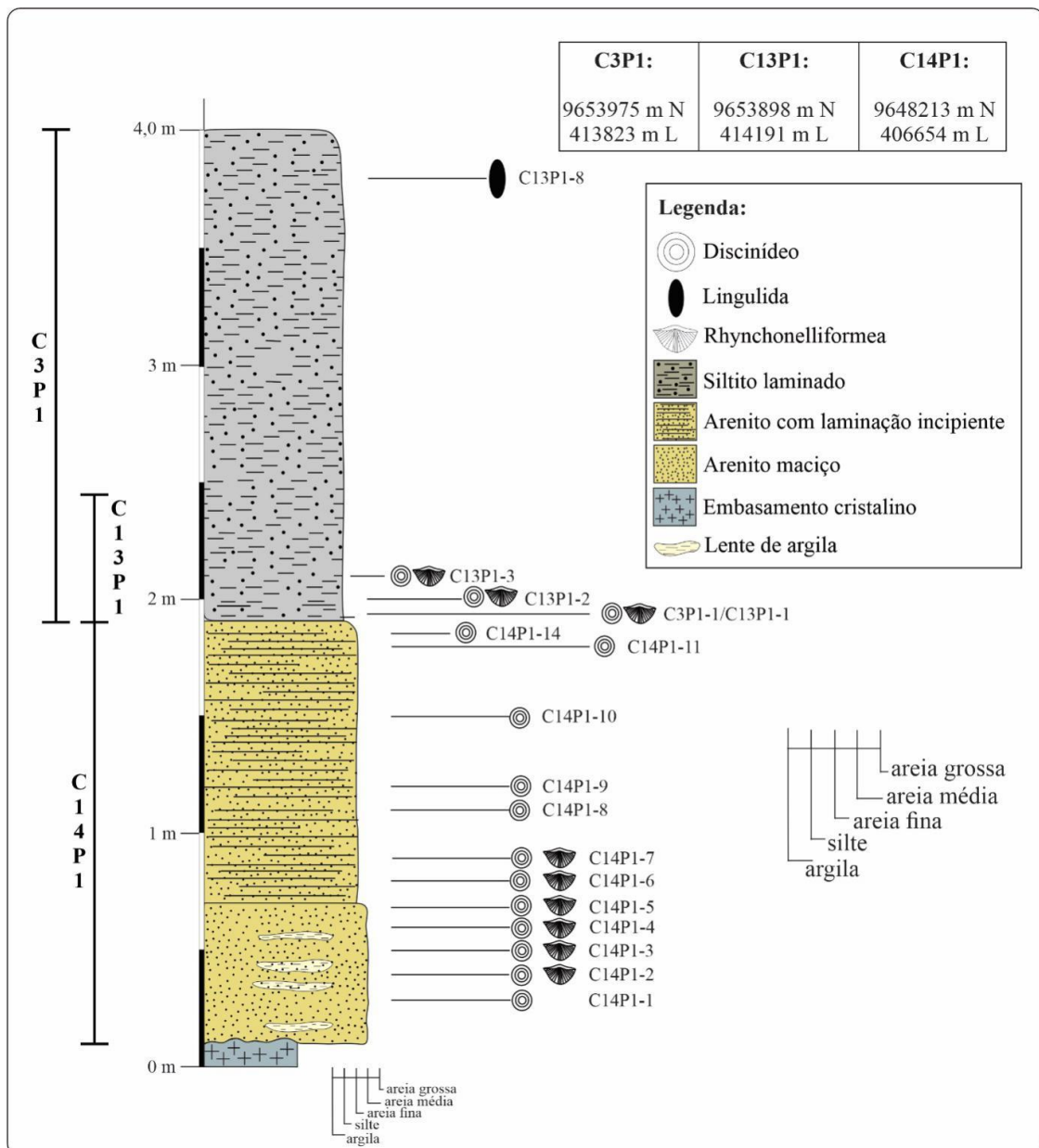


Figura 4- Perfil composto da seção analisada. Fonte: Corrêa (2020).

3.2 MÉTODOS

3.2.1 Pesquisa bibliográfica

O levantamento bibliográfico foi realizado a partir de consultas em livros, artigos científicos, teses e dissertações com seguintes assuntos: 1 – Morfologia, anatomia e hábitos de vida do filo Brachiopoda; 2 – Geologia da Bacia do Amazonas com ênfase na sucessão Ordovício-Devoniana; 3 – Estudos taxonômicos de braquiópodes do Siluriano e Devoniano; 4 – Ecologia dos braquiópodes fósseis e viventes; 5 – Paleobiogeografia do Devoniano; 6 – Métodos estatísticos empregados na paleobiogeografia; 7 – Distribuição estratigráfica dos braquiópodes no Devoniano da Bacia do Amazonas e das demais bacias paleozoicas brasileiras (Paraná, Parecis, Paranaíba e Jatobá); 8 – Principais expedições de cunho paleontológico e geológico na Bacia do Amazonas.

3.2.2 Consulta em acervos

Foram consultados acervos paleontológicos com o intuito de verificar os registros de braquiópodes devonianos da Bacia do Amazonas. Foram levantadas as seguintes informações: número de amostras depositadas em cada instituição, identificação dos taxóns, coletor e localização geográfica e geológica. Essas informações foram redigidas em uma planilha no Excel e foram disponibilizadas como material suplementar dos artigos II (*Schellwienella amazonensis* new species (Orthotetida, Brachiopoda): the first and oldest record of the genus from the Devonian of the Amazonas Basin (Manacapuru Formation – Lochkovian), North Brazil) e III (Relationships between brachiopod fauna (Lochkovian–Frasnian) from northwest Gondwana (Amazonas Basin) and environmental changes during the Devonian) desta tese.

O acervo do *New York State Museum* foi consultado por meio de correio eletrônico respondido pela Dr^a. Lisa Amati (Curadora da coleção de paleoinvertebrados). O acervo do *National Museum of Natural History* do Instituto de Smithsonian foi consultado através do banco de dados disponível no site do museu (<https://collections.nmnh.si.edu/search/paleo/>). O acervo do Museu de Ciências da Terra do Departamento Nacional de Produção/CPRM foi consultado por meio de correio eletrônico com o curador Dr. Rafael Costa da Silva. O acervo do Museu Paraense Emílio Goeldi foi consultado de forma presencial por meio do livro de registro e do sistema de banco de dados eletrônico.

3.2.3 Triagem, preparação e medidas das amostras

A fauna coletada durante o PSPP da UHBM é composta por restos vegetais, icnofósseis, graptólitos, braquiópodes, moluscos, malacostráceos, artrópodes, agnatos e palinomorfos. Primeiramente, foi realizada a separação dos braquiópodes em dois grandes grupos: Rhynchonelliformea e Linguliformea. Em seguida, ocorreu a preparação mecânica, por meio de técnicas manuais com a utilização de martelo, ponteira, pincéis, pinças, instrumentos odontológicos e fitas, visando destacar de melhor forma os aspectos morfológicos, com o intuito de facilitar a identificação dos fósseis. Com auxílio do retículo micrométrico e do paquímetro foram mensuradas dimensões (em milímetros) das valvas ventrais e dorsais, sendo estas comprimento (C), largura (L), razão entre comprimento/largura (C/L), tamanho das placas dentárias e do septo mediano, comprimento da região anterior, posterior e a espessura das possíveis ornamentações.

3.2.4 Aquisição e tratamento das imagens

Os exemplares com características morfológicas bem preservadas foram fotografados através da lente macro do Iphone 13 Pro, com resolução de 12 megapixels e abertura de diafragma $f/2.8$, onde essa câmera foi acoplada ao microscópio estereoscópio LEICA S8 APO. Três valvas de discinideos foram desagregadas da rocha (MPEG-3726, MPEG-3728 e MPEG-3746), para serem fotografadas no microscópio eletrônico de varredura (MEV) do campus de pesquisa do Museu Paraense Emílio Goeldi.

As imagens foram processadas utilizando o *software* Adobe Photoshop. Como as valvas dos braquiópodes estudados não são planas, foi necessário aplicar uma técnica de composição fotográfica para obter uma imagem com foco em toda a superfície da carapaça. Essa técnica envolve a captura de várias fotos, cada uma com o foco em uma região específica da valva. Primeiro, todas as imagens foram carregadas no Adobe Photoshop para alinhamento e mesclagem. Em seguida, as fotos foram alinhadas selecionando todas as camadas e, na aba 'Editar', escolhendo a opção 'Alinhar Camadas Automaticamente'. Após o alinhamento, a composição final foi realizada selecionando, na mesma aba, a opção 'Mesclar Camadas Automaticamente' e, em seguida, 'Empilhar Imagens'. O resultado é uma foto composta com foco nítido em toda a carapaça. As *plates* dos artigos foram elaboradas no software CorelDRAW.

Três valvas de discinideos foram desagregadas da rocha (MPEG-3726, MPEG-3728 e MPEG-3746), para serem fotografadas no microscópio eletrônico de varredura (MEV) do campus de pesquisa do Museu Paraense Emílio Goeldi.

3.2.5 Identificação taxonômica

A identificação taxonômica foi realizada mediante as observações macromorfológicas, microestruturais e de inserções musculares, e comparadas à bibliografia específica “Treatise on Invertebrate Paleontology Part H: Brachiopoda” (Williams *et al.*, 1997, 2000, 2004, 2007). A nomenclatura morfológica básica usada nas descrições está baseada principalmente em Williams *et al.* (1997). Bibliografias adicionais, com categorias hierarquicamente superiores foram consultadas, com o intuito de auxiliar e embasar as identificações de gêneros e espécies, tais com: Sharpe (1856), Clarke (1913), Lange (1943), Basset & Bryant (2006), Comniskey & Bosetti (2017), Carbonaro *et al.* (2018) e Rezende & Isaacson (2021).

3.2.6 Catalogação das amostras

Todos os exemplares estudados foram catalogados e depositados na coleção Paleontológica do Museu Paraense Emílio Goeldi (MPEG), Belém – PA; os dados foram inseridos no livro de registros, digitalizados no programa *Specify* e estão disponíveis na plataforma GBIF.

CAPÍTULO 4 FUNDAMENTAÇÃO TEÓRICA

4.1 PHYLUM BRACHIOPODA

O filo Brachiopoda Duméril, 1806 é representado por macroinvertebrados bentônicos, que tiveram sua primeira ocorrência no Cambriano, estendendo-se até os dias atuais e apresentam grande abundância nos depósitos marinhos rasos do Paleozoico Inferior (Clarkson 1992). Mais de 95% dos gêneros de braquiópodes descritos são extintos.

Durante muito tempo foram divididos em duas classes, Inarticulata (Linguliformea e Craniiformea) e Articulata (Rhynchonelliformea), este último representando mais de 95% dos organismos fósseis e vivos (Clarkson 1992, Williams *et al.* 2007). Com o avanço das pesquisas morfológicas, anatômicas e ontogenéticas, foi proposta uma nova classificação para o filo, subdividindo-o em três subfilos: Linguliformea, Craniiformea e Rhynchonelliformea (Williams *et al.* 1996); as denominações articulata e inarticulata se tornaram termos informais que ainda são muito usados. Os braquiópodes são formados por duas valvas, a ventral/pedicular e a dorsal/braquial, de composição organofosfática ou organocarbonática. O pedículo é o órgão responsável pela fixação do organismo ao substrato, que emerge por uma saída presente na valva ventral, e o lofóforo é o órgão encarregado de realizar a captura de alimento e possui sua estrutura de sustentação localizada principalmente na valva braquial (Clarkson 1992, Williams *et al.* 2007).

Os braquiópodes articulados lembram alguns moluscos bivalves, diferindo destes pelo plano de simetria, que nos braquiópodes é bilateral e passa através do meio de ambas as valvas (Figura 5); os braquiópodes apresentam conchas desiguais e uma lâmina peduncular que os fixa ao substrato (Prothero 2013). No caso dos moluscos, estes são equivalves, onde o plano de simetria passa entre as conchas, fazendo com que a concha direita seja a imagem espelhada da concha esquerda (Prothero 2013).

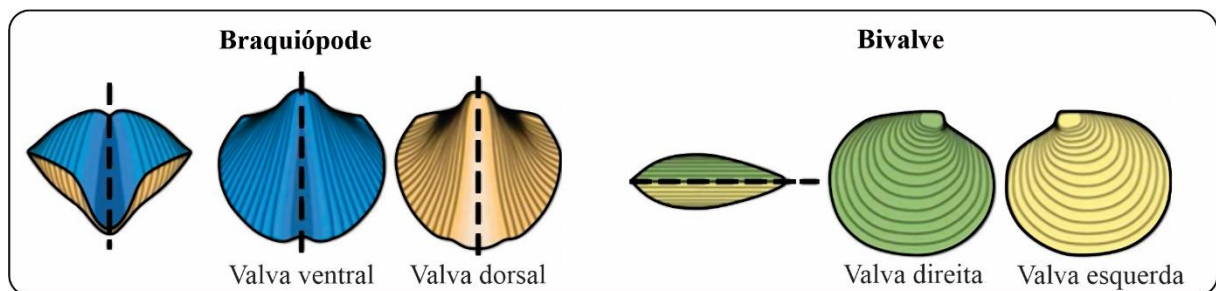


Figura 5- Plano de simetria dos braquiópodes e moluscos bivalves. Fonte: Modificado de Williams *et al.* (1997).

4.1.1 Morfologia / anatomia

4.1.1.1 Concha

A composição química das valvas dos braquiópodes é crucial para a classificação taxonômica do filo, sendo um dos principais critérios para distinguir os subfilos. Os Rhynchonelliformes e Craniiformes possuem valvas compostas predominantemente de carbonato de cálcio (CaCO_3), enquanto os Linguliformes têm valvas formadas principalmente por fosfato de cálcio (CaPO_4) (Clarkson 1992, Williams *et al.* 2007). A parte orgânica das valvas é constituída principalmente por quitina e proteína, com variações na proporção dessas substâncias entre os subfilos (Williams *et al.* 2007).

O *protegulum* é a primeira parte da concha a se formar e situa-se sobre o ápice das valvas; origina-se a partir de secreções expelidas pelo manto, e é a partir deste que o crescimento da concha ocorre. A posição do *protegulum* é determinante para a morfologia que a concha irá desenvolver; Williams *et al.* (2007) classificam o crescimento das valvas em três tipos: holoperiférico, mixoperiférico e hemiperiférico (Figura 6).

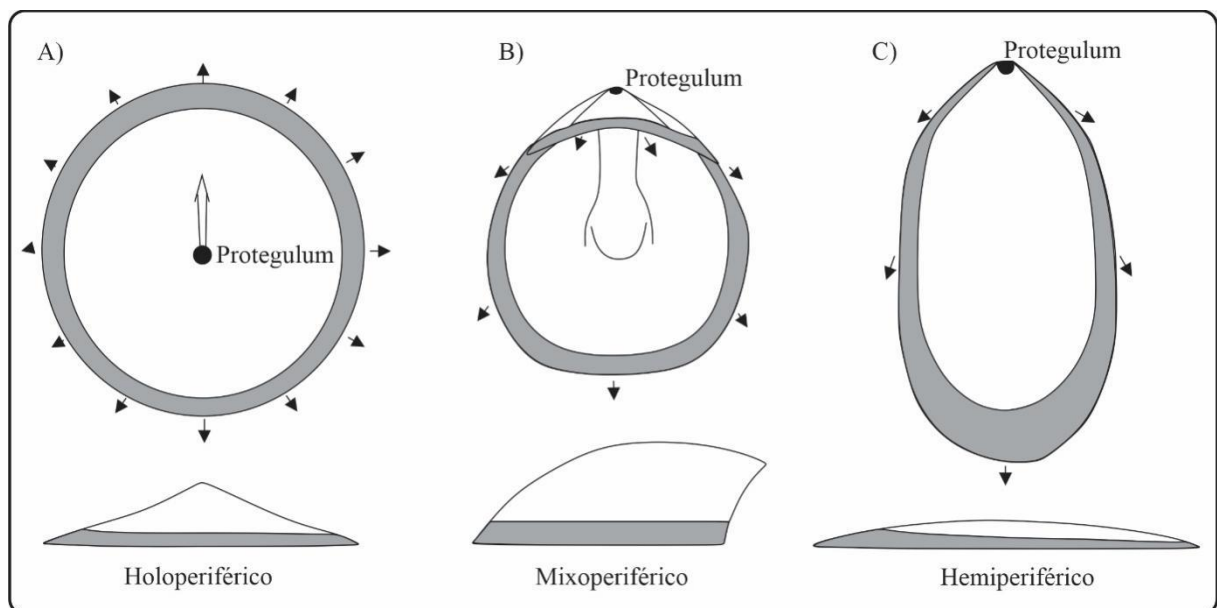


Figura 6- Formatos das conchas levando em consideração o posicionamento do protegulum. Fonte: Williams *et al.* (2007).

A área situada entre o *protegulum* e a região onde o pedículo emerge é chamada de posterior, e as extremidades opostas são denominadas como região anterior (Figura 7A) (Williams *et al.* 2007). A parte mais elevada das conchas geralmente é o ápice e ao redor dele fica o umbo. A linha de charneira pode ser reta (estrófica) ou curvada (astrófica). Entre o ápice

da valva ventral e a margem posterior da valva dorsal pode ocorrer uma superfície grande, plana ou curva que é conhecida como interárea (Williams *et al.* 2007).

O contorno das valvas é bastante variado, indo de circular até subtriangular (Figura 7B) (Williams *et al.* 2007). Outra característica morfológica importante da concha são as ornamentações (Figura 7C), que podem ser costelas, lamelas, carenas, espinhos e/ou espículas; caso não possua ornamentação, é denominada lisa (Williams *et al.* 2007). O termo linha de crescimento é utilizado de forma geral para designar qualquer tipo de ornamentação concêntrica não especificada, relacionada ao crescimento periódico, sendo bem comum nos discinídeos (Holmer 2001, Williams *et al.* 2007).

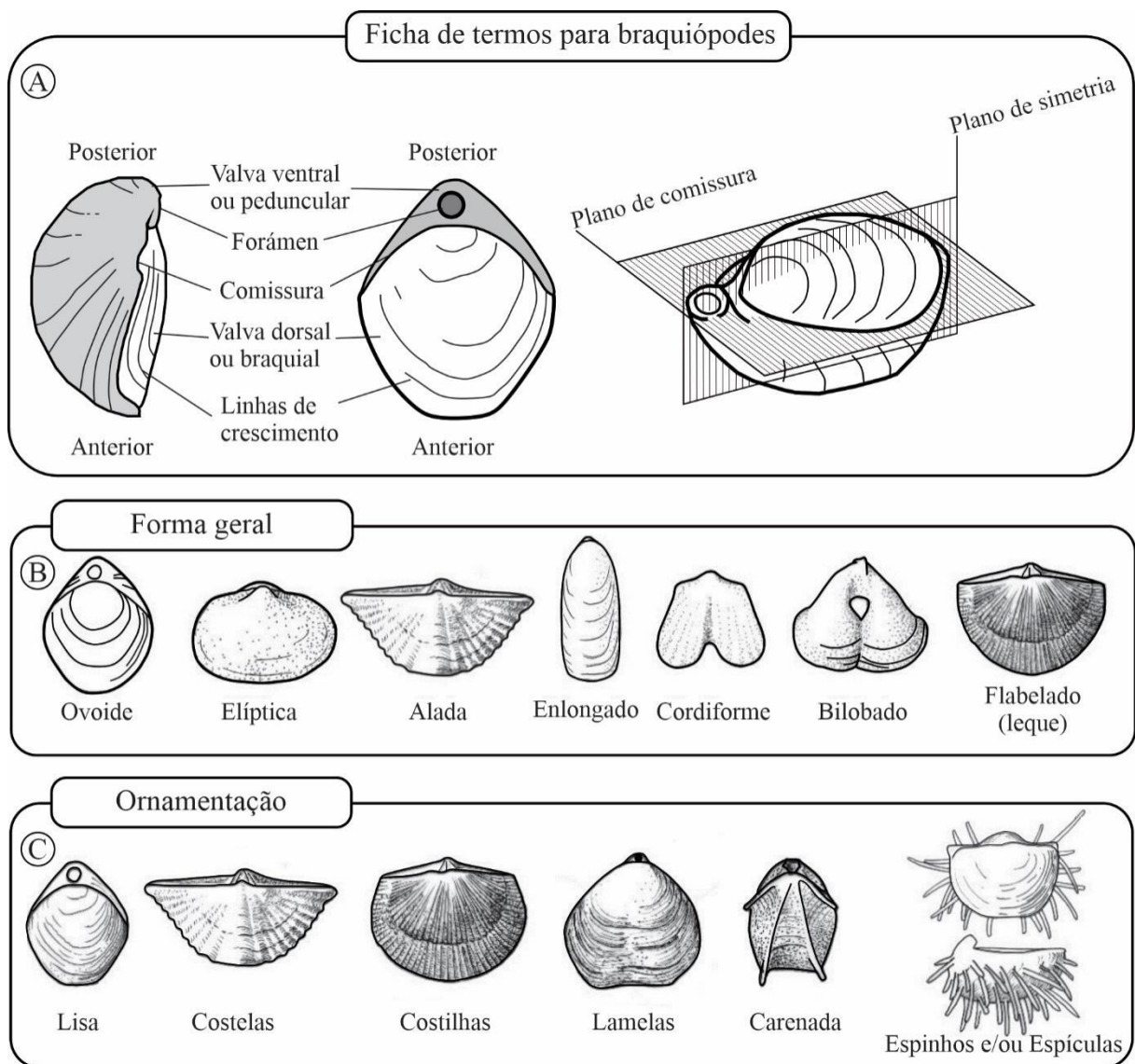


Figura 7- Características morfológicas descritivas das valvas dos braquiópodes. A) Características gerais, B) Formato das valvas e C) Ornamentação. Fonte: Mateus (2017).

As valvas podem apresentar microestruturas que são classificadas em pontuadas, pseudopontuadas e impontuadas (*punctate, pseudopunctate and impunctate*) (Williams *et al.* 2007). Se houver pequenos poros ou tubos que adentram a valva (camada interna e externa), são classificadas como pontuadas; se ocorrem hastes perpendiculares que penetram apenas na camada interna da valva são chamadas de pseudopontuadas; caso a valva seja lisa, sem nenhuma dessas características anteriores, é denominada impontuada (Figura 8) (Williams *et al.* 2007).

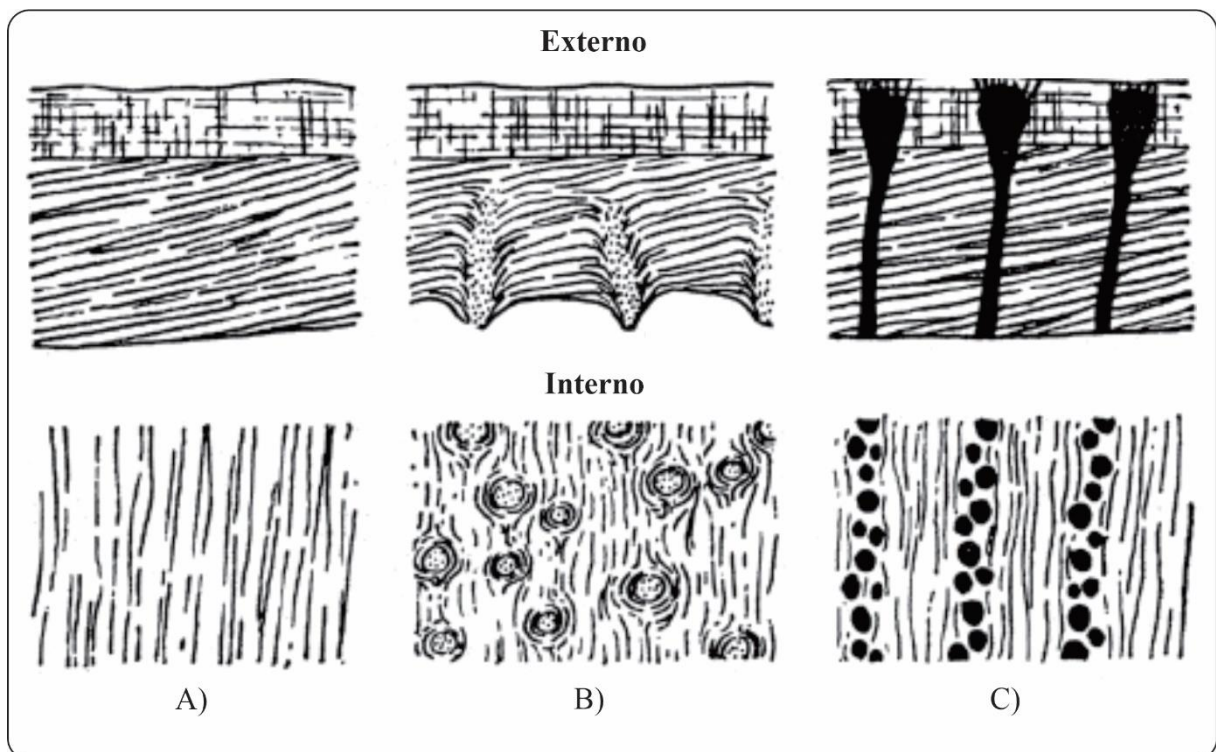


Figura 8- Microestruturas das valvas de braquiópodes. A) Pontuadas, B) Pseudopontuada e C) Impontuada. Fonte: (Prothero 2013).

As margens das comissuras ficam situadas nas bordas de ambas as valvas; suas formas podem variar de acordo com a presença de dobras e sulcos, tendo diversas classificações conforme apresentado na figura 9A (Williams *et al.* 2007). Levando em conta a morfologia vista do perfil lateral da valva, ela pode apresentar formas côncava, convexa ou plana (Figura 9B). As mais comuns nos fósseis do Paleozoico são as biconvexas, plano-convexas e côncavo-convexas (Williams *et al.* 2007).

4.1.1.2 Dentes e Fossetas dentárias

Os braquiópodes rhynchonelliformes possuem um mecanismo de articulação composto principalmente por dois dentes na valva ventral que se encaixam em duas fossetas dentárias na valva dorsal, que em conjunto com os músculos, são responsáveis pela abertura e fechamento

das conchas, por isso são chamados de articulados (Clarkson 1992, Williams *et al.* 2007). Os dentes são formados pelo epitélio externo, podendo apresentar formas circulares a triangulares e são suportados pelas placas dentárias. A linha imaginária que passa pela base dos dentes é chamada de eixo de articulação ou rotação (Williams *et al.* 2007). Nos linguliformes (inarticulados), esse mecanismo é ausente e a movimentação das conchas se dá única e exclusivamente pelos músculos (Williams *et al.* 2007).

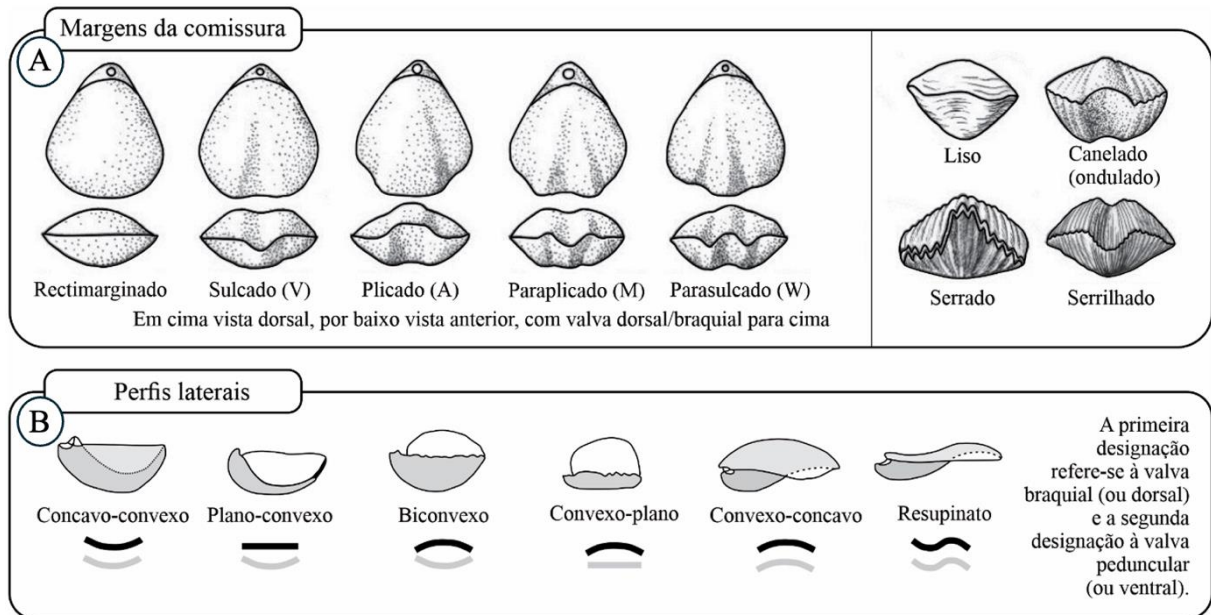


Figura 9- Características morfológicas descritivas das valvas de braquiópodes: A) Comissura e B) Perfis laterais. Fonte: Mateus (2017).

4.1.1.3 Pedículo

O pedículo ou pedúnculo (Figura 10A) é o órgão responsável pela fixação dos braquiópodes no substrato e emerge por uma abertura na valva ventral, chamada de forâmem (Clarkson 1992, Williams *et al.* 2007). Geralmente, nos rhynchonelliformes o forâmem fica situado próximo ao ápice, e é protegido pelo deltírio (valva ventral) e notírio (valva dorsal). Nos lingulídeos e discinídeos vivos, o pedículo é excretado pelo epitélio interno do manto ventral e está conectado apenas à valva ventral (Williams *et al.* 2007). Dificilmente é preservado nos registros geológicos, só em casos excepcionais (*fossil lagerstätten*), como nos lingulídeos do Cambriano da China (Figura 10B e 10C) (Zhang *et al.* 2005).

O desenvolvimento deste órgão reflete diretamente no hábito de vida dos braquiópodes. Nos lingulídeos, que são organismos infaunais (vivem dentro do substrato), o pedículo é longo, por vezes possuindo o mesmo comprimento da concha, já nos discinídeos, que são organismos epifaunais (que vivem sobre o substrato), o pedículo é curto e os músculos são mais desenvolvidos. Os craniiformes atuais não possuem pedículo em todas as fases de

desenvolvimento; estes são fixados ao substrato ou a outros organismos por meio de cimentação, resultante das propriedades adesivas do perióstraco (Williams *et al.* 2007). Nos rhynchonelliformes o pedículo tem formato cilíndrico, comprimento e diâmetro variáveis, com um núcleo de tecido conjuntivo e cutícula quitinosa externa. Em alguns espiriferídeos, o pedículo pode não se desenvolver, e a fixação ao substrato ocorre por meio de espinhos ou então são livres (Williams *et al.* 2007).

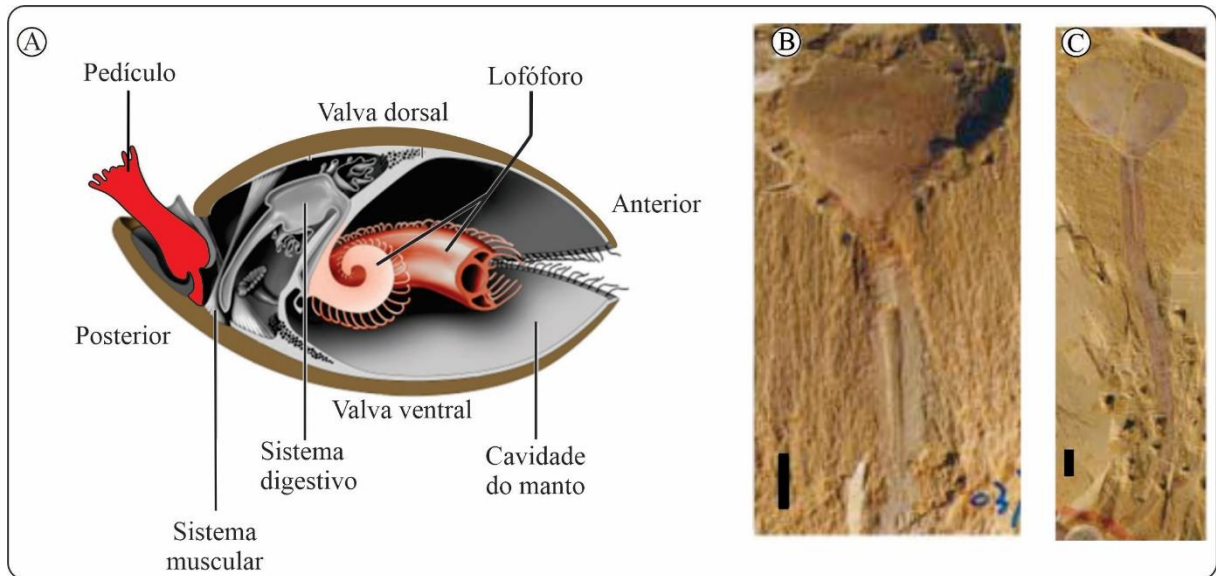


Figura 10- A) Morfologia do Pedículo. B) e C) Exemplos raros da preservação do pedículo em braquiópodes cambrianos da China. Fonte: A) Carlson (2016); B) e C) Zhang *et al.* (2005).

4.1.1.4 Musculatura

O principal papel dos músculos nos braquiópodes está relacionado à abertura e fechamento das valvas (Williams *et al.* 2007). A disposição destes é bem diferente entre os rhynchonelliformes e os linguliformes. Nos rhynchonelliformes a abertura e fechamento das conchas se dão através de um sistema articulatório (dentes e fossetas dentárias) em conjunto com os músculos, já nos linguliformes esses movimentos ocorrem única e exclusivamente em função dos músculos (Williams *et al.* 2007).

Nos rhynchonelliformes dois conjuntos de músculos atuam na abertura e fechamento das conchas: os adutores e didutores (Figura 11A). Os músculos adutores estão dispostos perpendicularmente entre as duas valvas, realizando o fechamento das conchas, enquanto os didutores estão situados na região posterior da valva ventral, responsáveis pela abertura das valvas. Os linguliformes, por terem apenas os músculos trabalhando na abertura e fechamento das valvas, possuem um sistema muscular mais complexo e desenvolvido. No caso dos

discinídeos, esse sistema é formado por dois pares de músculos adutores e três pares de músculos oblíquos (Figura 11B) (Williams *et al.* 2007).

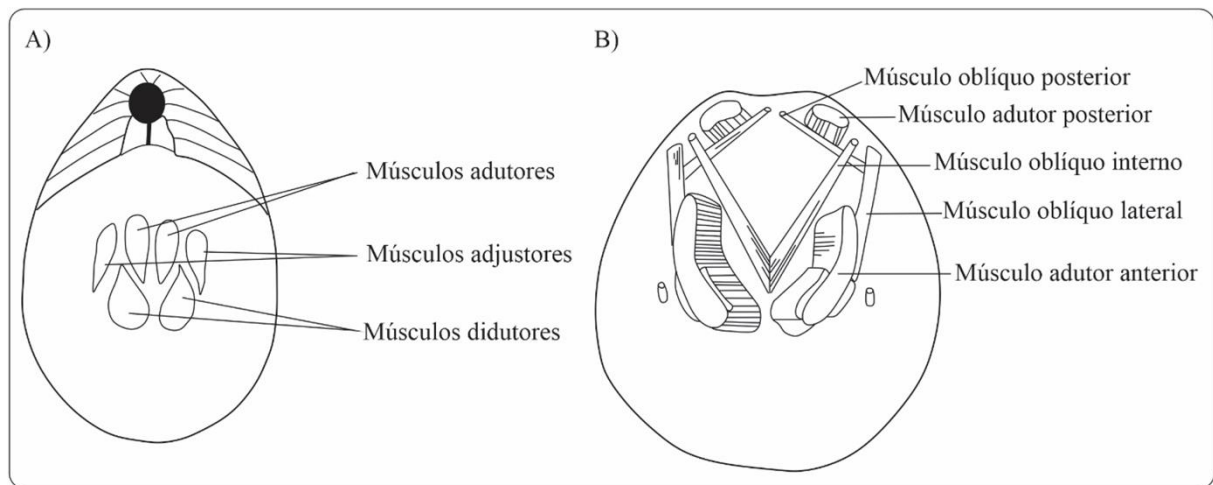


Figura 11- Musculatura dos braquiópodes. A) disposição dos músculos em alguns rhynchonelliformes e B) disposição dos músculos em alguns linguliformes. Fonte: (Williams *et al.* 2007).

4.1.1.5 Lofóforo

O lofóforo é o órgão encarregado de capturar alimentos, que pode também auxiliar na respiração dos braquiópodes (Williams *et al.* 2007). A maior parte de sua estrutura está posicionada na valva braquial, entre os dois lobos do manto, ocupando grande parte do espaço intermediário. Quando totalmente desenvolvido possui a morfologia de um tubo, assentado em formas variáveis (Williams *et al.* 2007, Carlson 2016).

Os movimentos do lofóforo são limitados, embora casos excepcionais de extensão transcomissural tenham sido registrados em alguns rhynchonellidas atuais (Williams *et al.* 2007). Nos linguliformes o suporte esquelético é restrito; conseqüentemente, a musculatura que auxilia o órgão é melhor desenvolvida. Alguns linguliformes possuem músculos extras ligados ao lofóforo, responsáveis por controlar a posição do órgão em relação à valva braquial e à parede anterior do corpo. No caso dos discinídeos e craniídeos, estes são representados por um pequeno par de músculos retratores braquiais, localizados na parte lateral da valva braquial (Carlson 2016, Williams *et al.* 2007).

4.1.1.6 Celoma e manto

A cavidade do celoma está situada na parte interna posterior do braquiópodes, preenchida por um fluido coagulável que transporta uma variedade de células livres (Figura 12). É na cavidade do celoma que estão alojados a maior parte dos órgãos internos, como os músculos, canal alimentar, órgãos excretores e parte dos órgãos sexuais (Williams *et al.* 2007).

Outros espaços celômicos existem dentro dos lobos do lofóforo e no pedículo de braquiópodes linguliformes (Williams *et al.* 2007).

Nos braquiópodes atuais a parede do corpo é revestida pelo epitélio ectodérmico, que é dividido em interno e externo (Williams *et al.* 2007, Camacho & Longobucco 2007). Os dois epitélios são contínuos ao longo da margem do manto e o contato entre eles ocorre dentro da borda da valva, no fundo do sulco periférico (Williams *et al.* 2007, Camacho & Longobucco 2007). O epitélio interno cobre a cavidade do manto e se estende até o epitélio ciliado do lofóforo, enquanto o epitélio externo é responsável pela secreção do exoesqueleto biomineralizado (Williams *et al.* 2007, Camacho & Longobucco 2007).

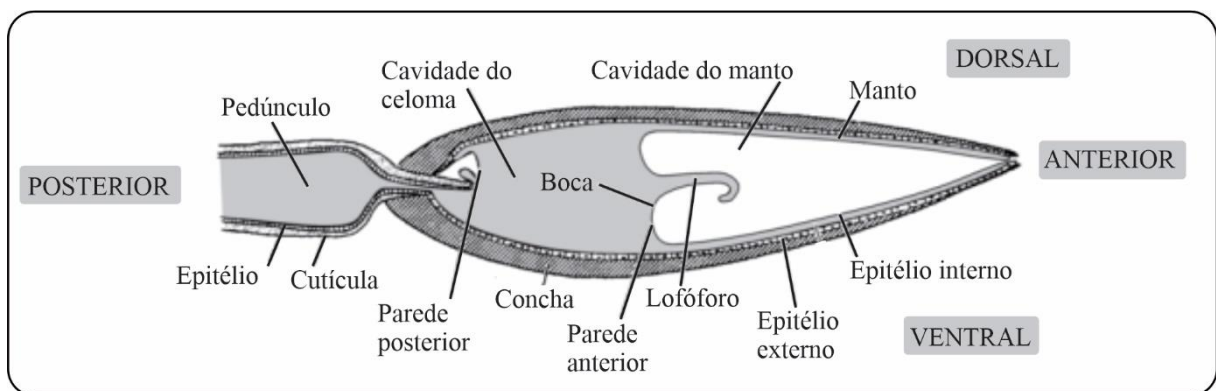


Figura 12- Cavidade do celoma e manto em braquiópodes. Fonte: Williams *et al.* (1997).

4.1.2 Classificação

Os braquiópodes foram classificados erroneamente como moluscos bivalves até o final do século XIX, quando os cientistas começaram a investigar a anatomia interna e verificaram que não se pareciam em nada com a de um molusco. O Filo Brachiopoda, foi proposto em 1806 por André Marie Constant Duméril. Os braquiópodes foram definidos como invertebrados celomados, solitários, bilateralmente simétricos, com o plano de simetria passando no meio das valvas, compostos por duas valvas: uma ventral/peduncular (geralmente a maior) e uma valva dorsal/braquial. Sua composição pode ser organofosfática ou organocarbonática, com lofóforo, canal alimentar, com ou sem ânus e sistema nervoso subepitelial, fixados ao substrato por um pedículo, ou por cimentação. Podem ser divididos em três subfilos (Tabela 1): Linguliformea, Craniiformea e Rhynchonelliformea (Williams *et al.* 1996, Williams *et al.* 2007).

Tabela 1- Sistemática do filo Brachiopoda.

Filo Brachiopoda	
Subfilo Linguliformea	Classe Kutorginata
Classe Lingulata	Ordem Kutorginida
Ordem Lingulida	Classe Strophomenata
Ordem Acrotretida	Ordem Strophomenida
Ordem Siphonotretida	Ordem Billingsellida
Classe Paterinata	Ordem Productida
Ordem Paterinida	Ordem Orthotetida
Subfilo Craniiformea	Classe Rhynchonellata
Classe Craniata	Ordem Protorthida
Ordem Craniida	Ordem Orthida
Ordem Craniopsida	Ordem Pentamerida
Ordem Trimerellida	Ordem Rhynchonellida
Subfilo Rhynchonelliformea	Ordem Atrypida
Classe Chileata	Ordem Athyridida
Ordem Chileida	Ordem Spiriferida
Ordem Dictyonellida	Ordem Spiriferinida
Classe Obolellata	Ordem Thecideida
Ordem Obolellida	Ordem Terebratulida
Ordem Naukatida	

Fonte: Williams *et al.* (2007).

O registro mais antigo é do Cambriano Inferior, estendendo-se desde então por quase todos os períodos geológicos, com cerca de 30.000 espécies fósseis registradas (Williams *et al.* 2007). Embora tenha uma longa distribuição na escala do tempo, foi durante a era Paleozoica que teve sua maior radiação (Figura 13), abundância e diversidade, muito influenciadas pelas mudanças tectônicas e ambientais favoráveis (Williams *et al.* 2007).

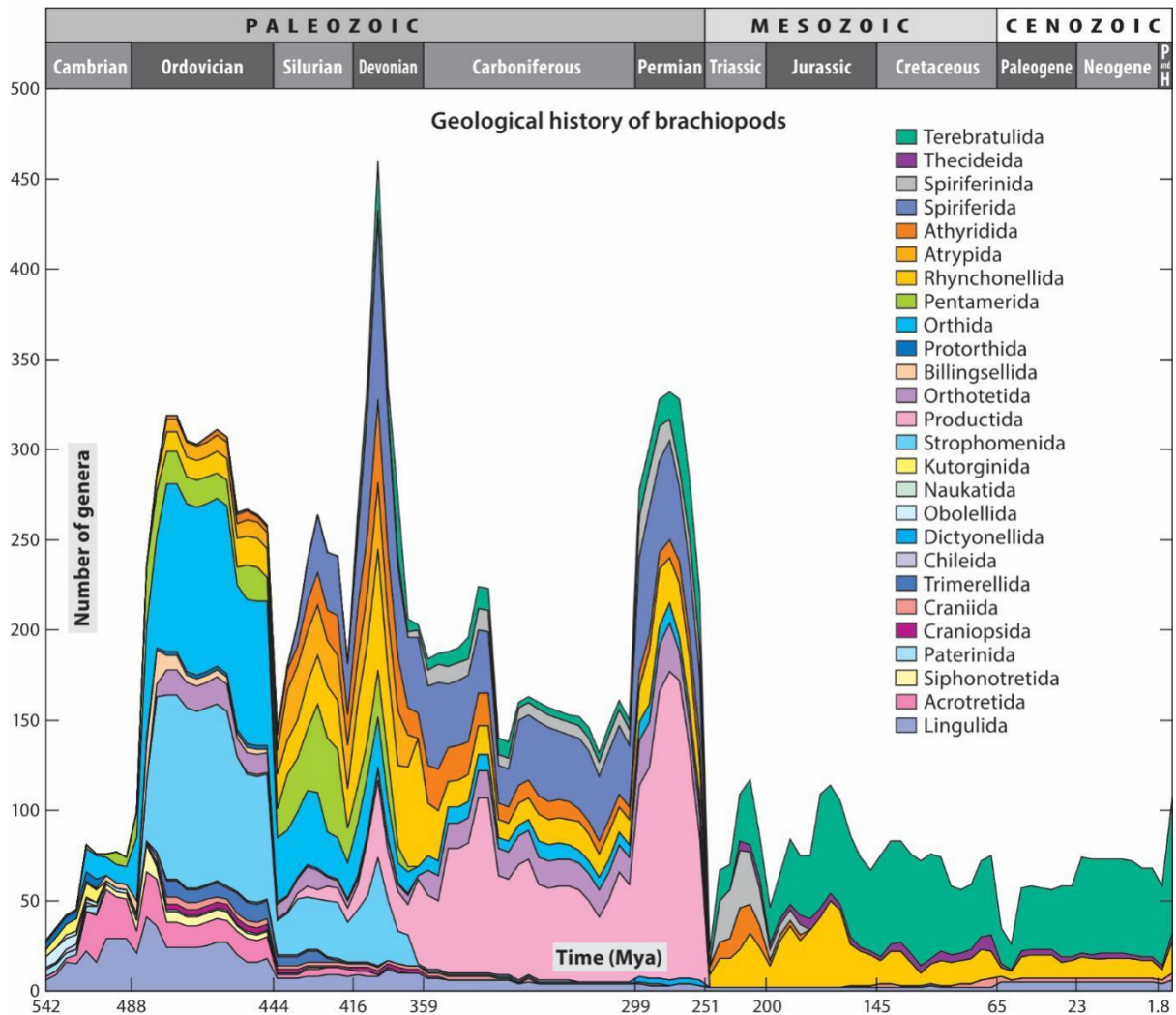


Figura 13- Diversidade de gêneros ao longo do Fanerozoico. Fonte: Carlson (2016).

A extinção em massa do Permiano-Triássico foi o período mais crítico, ocasionando o extermínio de diversos braquiópodes (*e.g.*, Orthida e Productida) (Williams *et al.* 2007, Emig *et al.* 2013). Desde então, a diversidade e abundância dos braquiópodes foram drasticamente reduzidas. Hoje esses organismos ainda persistem em diferentes ambientes marinhos ao redor do mundo, embora em números reduzidos em comparação com o passado. Atualmente, existem cerca de 116 gêneros e 391 espécies de braquiópodes vivos, pertencentes às ordens Lingulida, Rhynchonellida, Terebratulida e Thecideida (Emig *et al.* 2013). Os braquiópodes vivos habitam diversas regiões marinhas, sendo mais comuns nos oceanos Ártico, Antártico e Índico, ocorrendo desde zonas intertidais até profundidades superiores a 2.000 metros, dependendo da espécie e das condições ambientais (Williams *et al.* 2007, Emig *et al.* 2013).

4.1.2.1 Subfilo Linguliformea

Representantes deste subfilo possuem conchas organofosfáticas, desenvolvidas sem reversão do manto a partir de larvas planctotróficas. Estes organismos são inarticulados, ou

seja, não possuem um sistema articulatorio, e geralmente apresentam linhas de crescimento. O pedículo é bem desenvolvido, com extensão celômica emergindo entre as valvas ou através do forâmem, e o trato digestivo possui ânus (Williams *et al.* 1996, Holmer 2001). Esses organismos são registrados em estratos cambrianos e ocorrem até os dias atuais. O subfilo comporta duas classes (Lingulata e Paterinata) e quatro ordens (Lingulida, Acrotretida, Siphonotretida e Paterinida) (Williams *et al.* 1996).

Entre os lingulídeos, destaca-se o gênero *Lingula*, cuja forma linguliforme, refletindo bem o hábito de vida endobionte desses organismos, permanece quase inalterada desde o Cambriano. Por isso, *Lingula* é considerado por alguns pesquisadores como um "fóssil vivo" (Emig 2003, Prothero 2013). Este termo informal foi frequentemente utilizado para se referir a espécies vivas que têm grande semelhança com espécies extintas, mas caiu em desuso; existe recomendações científica para o abandono do termo, por se tratar de conceito intuitivo e de simples morfologia de determinadas características da espécie (como a anatomia e aspecto geral do corpo), que são ressaltados de maneira arbitrária (Romano *et al.* 2007).

A classe Lingulata foi proposta por Gorjansky & Popov (1985) e é caracterizada principalmente por padrões morfológicos internos. Suas principais características incluem uma estrutura de concha com canais verticais, um mecanismo hidráulico de abertura da concha acionado por músculos dérmicos bem desenvolvidos na parede anterior do corpo, e um sistema muscular composto por adutores posteriores simples ou pareados, além de três ou quatro pares de músculos oblíquos. O sistema de canais do manto, que direciona os ramos terminais periféricos e mediais, e as gônadas confinadas à cavidade corporal também são distintivos (Williams *et al.* 1996, Holmer 2001). A classe Lingulata inclui 22 famílias extintas e duas que ainda existem, Lingulidae e Discinidae (Williams *et al.* 2000).

Os braquiópodes da classe Paterinata apresentam características morfológicas e anatômicas que os diferenciam da classe Lingulata. Entre essas características estão lóbulos e manto fundidos, interáreas com deltírio e nototírio, sistema muscular formado por músculos didutores, sistemas de canais de manto com gônadas, e fixação ao substrato por meio de uma almofada cuticular do manto ventral (Williams *et al.* 1998, Laurie 1987). A classe Paterinata foi proposta por Williams *et al.* (1998) e inclui duas famílias (Cryptotretidae e Paterinidae) e 11 gêneros. O registro mais antigo dessa classe é do Cambriano, enquanto o mais recente é do Ordoviciano (Williams *et al.* 2000, Holmer 2001).

4.1.2.2 Subfilo Rhynchonelliformea

Este subfilo constitui-se de conchas articuladas, calcíticas, com duas camadas: uma primária (externa) lamelar e uma camada secundária (interna) fibrosa. A linha de charneira é bem desenvolvida, formada pela margem cardinal posterior das valvas. O sistema articulatório é composto por um par de dentes ventrais e fossetas dorsais, o pedículo se desenvolve a partir de um rudimento larval e é preenchido por tecido conjuntivo (Williams *et al.* 2007). Devido ao auxílio do sistema articulatório na movimentação das conchas, a musculatura desses organismos é mais simples quando comparado com a dos linguliformes, formada por dois músculos adutores agrupados (trabalham para fechar as valvas) e um par de músculos didutores (trabalham para abrir as valvas). O trato digestivo não tem ânus, o intestino é cego, o lofóforo não possui tentáculo medial e é sustentado por extensões calcíticas da linha de charneira e canais do manto ramificados com gônadas (Williams *et al.* 2007).

Os rhynchonelliformes abrangem cerca de 95% de todos os gêneros de braquiópodes, representados por cinco classes (Chileata, Obolellata, Kutorginata, Strophomenata e Rhynchonellata) e 19 ordens (Chileida, Dictyonellida, Obolellida, Naukatida, Kutorginida, Strophomenida, Billingsellida, Productida, Orthotetida, Protorthida, Orthida, Pentamerida, Rhynchonellida, Atrypida, Athyridida, Spiriferida, Spiriferinida, Thecideida e Terebratulida). Dentre os três subfilos, são os que mais possuem representantes nos mares atuais, com 30 espécies e 22 gêneros vivos (Kowalewski *et al.* 2002, Williams *et al.* 2007). As espécies existentes raramente são encontradas em águas tropicais, sendo mais comuns em mares temperados e polares mais profundos. Já os rhynchonelliformes paleozoicos eram mais comuns em regiões tropicais (Kowalewski *et al.* 2002).

A Classe Chileata foi proposta por Williams *et al.* (1996), composta por duas ordens Chileida e Dictyonellida, caracterizada por braquiópodes cuja morfologia das conchas é biconvexa, estrófica ou astrófica, com crescimento mixoperiférico na valva ventral e hemiperiférico na valva dorsal. O umbo da valva ventral possui uma perfuração que é maior na região anterior, restringindo-se na região posterior por uma placa (colleplax). Os músculos oblíquos internos são situados na parte apical dorsal, com canais do manto pinados; com registros no Cambriano Inferior – Permiano (Williams *et al.* 1996, 2000, 2007).

A Classe Obolellata também foi proposta por Williams *et al.* (1996), possui um curto registro geológico indo do Cambriano Inferior ao Cambriano Médio e comporta duas ordens (Obolellida e Naukatida). A referida classe é caracterizada por conchas biconvexa com parede foliada e/ou pontilhada, e crescimento das valvas hemiperiférico, interáreas bem definidas,

sendo a interárea ventral com deltídio geralmente coberto por pseudodeltídio côncavo. Os músculos oblíquos internos são fixados na valva dorsal, na região pósteromediana, e as larvas são provavelmente planctotróficas (Williams *et al.* 1996, 2007).

Os braquiópodes da Classe Kutorginata possuem conchas ventribiconvexas, estróficas, com uma camada secundária fibrosa e crescimento mixoperiférico. A margem anterior é retimarginada e raramente sulcada, enquanto a margem posterior larga, reta e com grande abertura mediana. Deltírio triangular, coberto por pseudodeltídio convexo, umbo ventral é subcônico com pequeno forâmen apical redondo, interárea dorsal é dividida por nototírio amplo. As cicatrizes dos músculos adutores dorsais são dispostas radialmente e impressas no assoalho da cavidade nototíria, ausência de dentes e fossetas, articulação é incipiente nas bordas das interáreas e trato digestivo provavelmente aberto com ânus (Williams *et al.* 1996, 2007). A classe conta apenas com uma ordem (Kutorginida), registrada no Cambriano (Williams *et al.* 1996, 2007).

A Classe Strophomenata é a segunda maior em termos de diversidade, ficando atrás apenas dos rhynchonelliformes, tendo, por isso, certa variação em suas características morfológicas e anatômicas diagnósticas. As conchas possuem camada secundária lamelar cruzada, excepcionalmente fibrosa nos grupos mais antigos, e são comumente pseudopontuadas, raramente extropontuadas ou pontuadas (apenas nos mais primitivos). O contorno e o perfil das conchas variam, principalmente entre os Productida, embora muito comum serem plano-convexos e esporadicamente côncavo-convexos (no Strophomenida). A linha de charneira é estrófica, geralmente com interárea ventral moderada a alta e interárea dorsal reduzida, o deltírio e o nototírio cobertos, forâmen supra-apical desenvolvido em formas juvenis, perdendo-se nos adultos. Espinhos tubulares são desenvolvidos apenas em Productida do Paleozoico Superior. Os dentes deltíodotes são simples, transversais ou pontiagudos, às vezes atrofiados, fossas dentárias geralmente definidas por cristas baixas e paralelas à linha de charneira; bases dorsais dos músculos didutores são inseridas na plataforma nototíria ou normalmente em processos cardinais proeminentes de morfologia variada; bases ventrais fixadas lateralmente às cicatrizes adutoras localizadas medialmente. Raramente possuem suportes lofóforos, seja como braquióforos ou cristas dorsais elevadas. Os sistemas de canais do manto são sacados a pinados, pouco conhecido nos grupos mais jovens (Williams *et al.* 1996, 2007). As larvas são supostamente planctotróficas, ocorrem desde o Cambriano ao Permiano e abrangendo quatro ordens: Strophomenida, Billingsellida, Productida e Orthotetida (Williams *et al.* 1996, 2007).

Os rhynchonellatas compreendem a maior classe dentre os braquiópodes, composta por dez ordens (Protorthida, Orthida, Pentamerida, Rhynchonellida, Atrypida, Athyridida, Spiriferida, Spiriferinida, Thecidea e Terebratulida) e aproximadamente 3.000 gêneros, com registro estratigráfico indo do Cambriano ao Holoceno (Williams *et al.* 2007); possuem conchas biconvexas, estróficas ou astróficas, com camada secundária fibrosa, pontuada, endopontuada ou impontuada; articulação é composta por dentes de deltidiodontes ou citomatodontes, sustentados por braquióforos ou pela linha da charneira; a interárea e nototírio geralmente são vestigiais ou ausentes, embora possam ser bem desenvolvidos em alguns grupos especializados; em alguns rhynchonellatas as placas dentárias podem convergir para formar uma plataforma póstero-mediana (espondílio); as impressões dos músculos adutores na valva ventral são flanqueadas ou cercadas pelas impressões dos músculos didutores, ajustadores posicionados lateralmente; cicatrizes adutoras dorsais são petalóides ou agrupadas e quadripartidas; sistemas de canais do manto podem variar entre impressões sacadas, digitadas ou pinadas; as larvas foram planctotróficas em diversos grupos primitivos (desde do Cambriano), porém, a partir do Siluriano, predominou a lecitotrófica (Williams *et al.* 1996, 2007). Na tabela 2 estão listados os principais parâmetros que diferenciam os três subfilos.

Tabela 2- Principais características que diferenciam os subfilos de braquiópodes.

Características	Linguliformea	Craniiformea	Rhynchonelliformea
Composição da valva	Fosfato de cálcio	Carbonato de cálcio	Carbonato de cálcio
Valvas articuladas	Não	Não	Sim
Cerdas nas margens das valvas	Sim	Não	Sim
Pedículo	Sim, bem desenvolvido com extensão celômica	Ausente, valva ventral cimentada ao substrato	Sim, sem extensão celômica
Ânus	Sim	Sim	Não
Tipo de Larva	Planctotróficas	Lecitotróficas	Lecitotróficas
Larva com valva	Sim	Não	Não
Larva com tentáculos	Sim	Não	Não

Fonte: Williams *et al.* (1996).

4.2 PALEOBIOGEOGRAFIA DO DEVONIANO

O Devoniano foi marcado por diversas dinâmicas climáticas, tectônicas e evolutivas (Dowding *et al.* 2021). A distribuição global de invertebrados marinhos (braquiópodes, corais, trilobitas e gastrópodes) sugere padrões globais de biorregionalizações principalmente para o intervalo Devoniano Inferior – Médio (Boucot *et al.* 1969, Penn-Clarke & Harper 2020). O

caráter provincial dessas faunas devonianas na América do Sul, África do Sul e Ilhas Malvinas foi identificado por cientistas desde o século XIX (Penn-Clarke & Harper 2020). No Brasil, Clarke (1913) destacou que a fauna de invertebrados da Formação Ererê (Bacia do Amazonas) possuía uma afinidade “boreal” (Figura 14). As regiões mais ao sul no Devoniano (parte da América do Sul, África do Sul e Ilhas Malvinas) foram rotuladas como “Austral” (Clarke 1913).

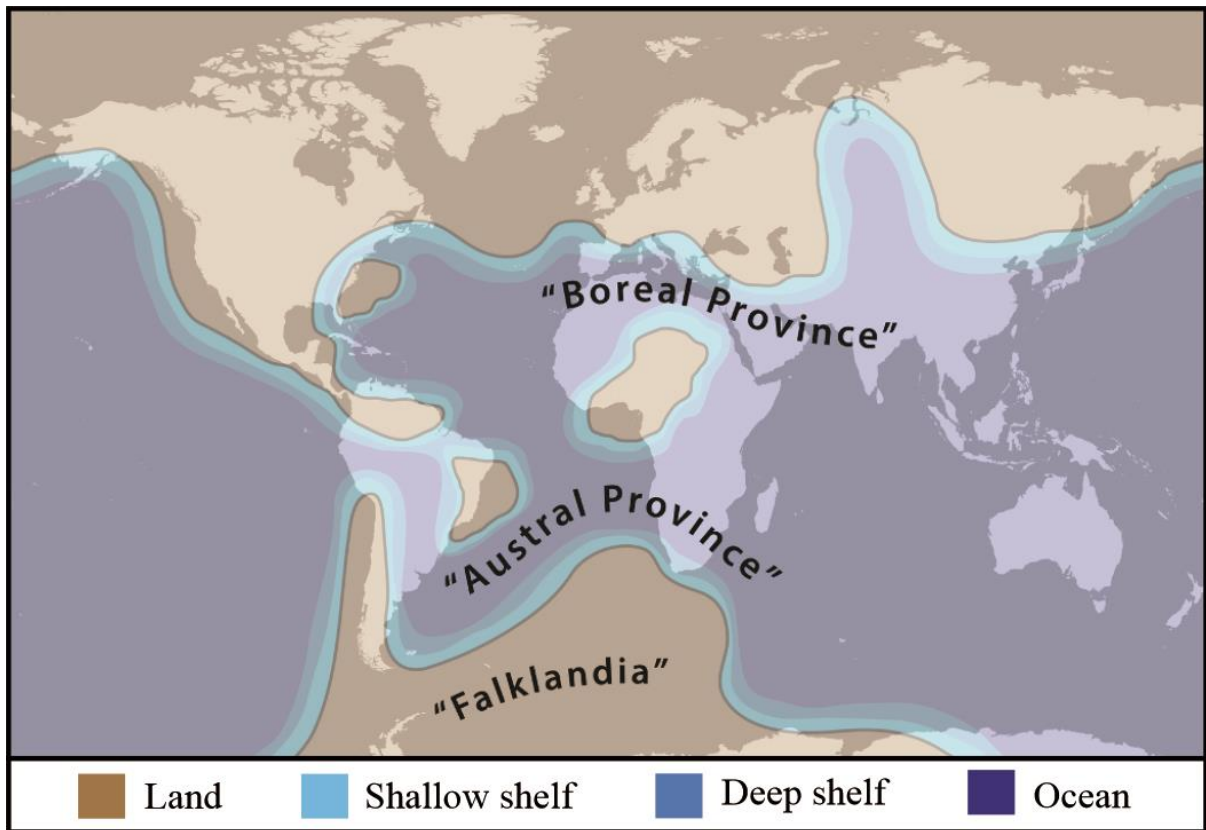


Figura 14-Localização das províncias paleobiogeográficas “Boreal” ao norte e “Austral” ao sul e do hipotético continente “Falklandia”, reconhecidos por Clarke (1913). Fonte do mapa: Penn-Clarke (2019).

Richter (1941) e Richter & Richter (1942) ao analisarem a natureza distinta dos trilobitas calmonídeos (totalmente endêmicos), sugeriram que a fauna das Ilhas Malvinas (Falkland Islands) e da região do Cabo, eram bem diferentes das demais regiões (Austral e Boreal). Foram os primeiros autores a introduzir o termo “Malvinocaffrischen Provinz”. Posteriormente, Boucot *et al.* (1969) e Johnson & Boucot (1973) expandiram os limites geográficos do Reino Malvinocáfrica para a Antártida e Gana (Figura 15).

No decorrer do século XX, três principais áreas paleobiogeográficas globalmente extensas foram reconhecidas: as províncias Malvinocáfrica, Velho Mundo e Apalaches (esta última, posteriormente, passou a ser chamada Américas Orientais) (Boucot *et al.* 1969, Johnson *et al.* 1973). Boucot (1975) propôs que o termo “província” Malvinocáfrica fosse substituído por “reino” Malvinocáfrico, unidade biogeográfica superior a província segundo Kauffman

(1973). O Reino Malvinocáfrico ocupou regiões polares a subpolares, situadas em altas latitudes (60°S – 90°S), com águas frias na América do Sul, África do Sul e Ilhas Malvinas (Boucot *et al.* 1969, Copper 1977, Boucot 1985, Cocks & Torsvik 2002, Torsvik & Cocks 2011, 2013, Boucot *et al.* 2013). Dentre os três reinos paleobiogeográficos devonianos, o reino Malvinocáfrico é o único não subdividido em regiões ou províncias amplamente aceitas (Dowding & Ebach 2018, 2019, Penn-Clarke & Harper 2020). Penn-Clarke & Harper (2020) propuseram a substituição de “kaffric” (Malvinokaffric) por “xhosan”; Dowding *et al.* (2021) concordaram e sugeriram que o termo “Malvinoxhosan” seja usado para todos os trabalhos futuros.

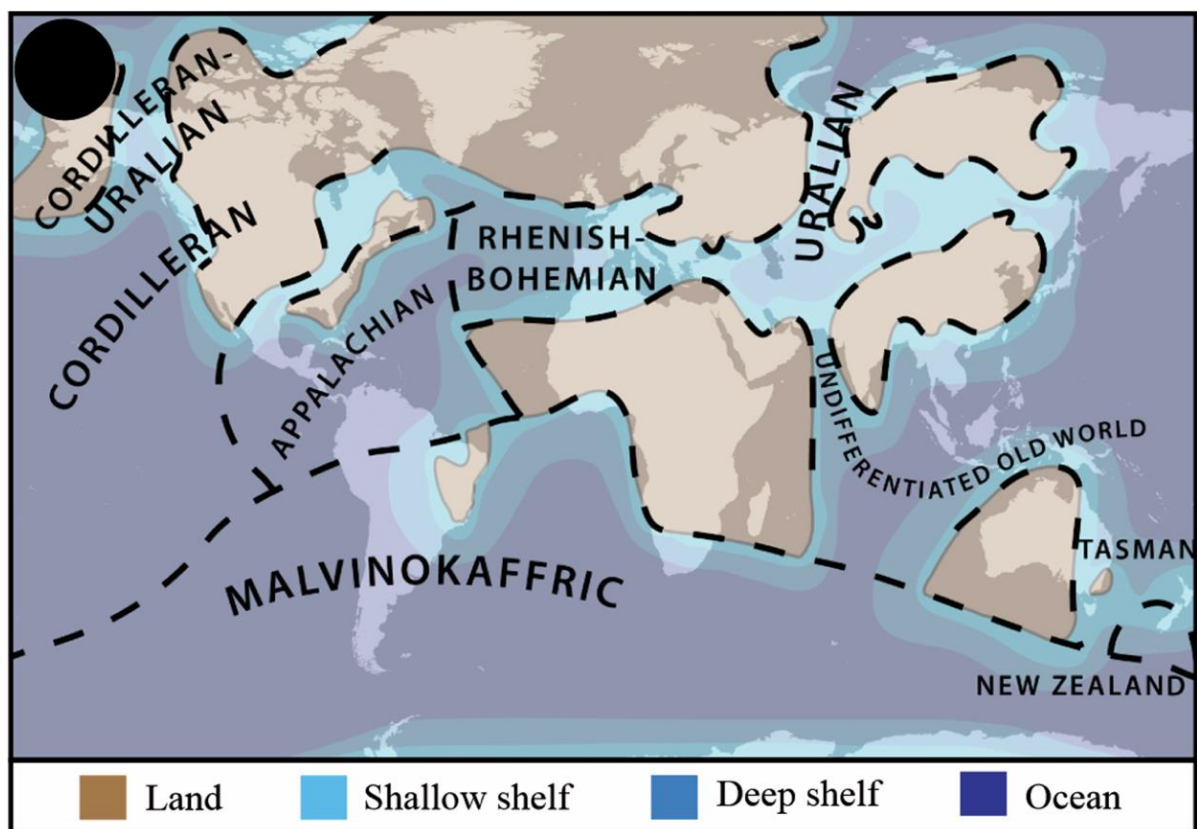


Figura 15- Distribuição de reinos e províncias paleobiogeográficas, com base nas distribuições de táxons endêmicos de braquiópodes, proposta por Boucot *et al.* (1969). Fonte do mapa: Penn-Clarke (2019).

O Reino do Velho Mundo era descendente do Reino Siluriano do Norte, caracterizado por regiões tropicais e subtropicais, com águas quentes, situadas em baixas latitudes (30°N – 30°S), que abrangeu durante o Devoniano a Europa, África do Norte, Ásia, Austrália, Nova Zelândia e o oeste da América do Norte (Boucot *et al.* 1969, Boucot 1971, 1975, 1988). É subdividido em quatro regiões: Região dos Urais, Região da Cordilheira, Região Sul da China e Região da Renânia-Boêmia (Figura 16).

No Reino das Américas Orientais, as águas eram temperadas, situado entre os reinos do Velho mundo e Malvinocáfrico, nas latitudes médias a baixas ($30^{\circ}\text{S} - 60^{\circ}\text{S}$), englobando o Leste da América do Norte e parte da América do Sul (Colômbia e Venezuela) (Boucot *et al.* 1969, Boucot 1971, 1975, 1988). É dividido em quatro províncias: Província de Appohimchi, Província de Nevada, Província da Bacia de Michigan e Província Venezuela-Colômbia.

O Reino Malvinocáfrico é marcado por uma fauna de baixa diversidade, com a ausência de grupos como conodontes, graptólitos e esponjas, e altas incidências de endemismo, principalmente de trilobitas (Phacopide e Proetide) e braquiópodes (terebratulidas, productidas, orthotetidas, spiriferidas e athyrididas) (Penn-Clarke & Harper 2020). A ausência ou raridade de organismos termófilos (goniatites e conodontes) reforça a hipótese de condições polares a subpolares (Boucot *et al.* 1969, Copper 1977, Boucot 1985, 1988).

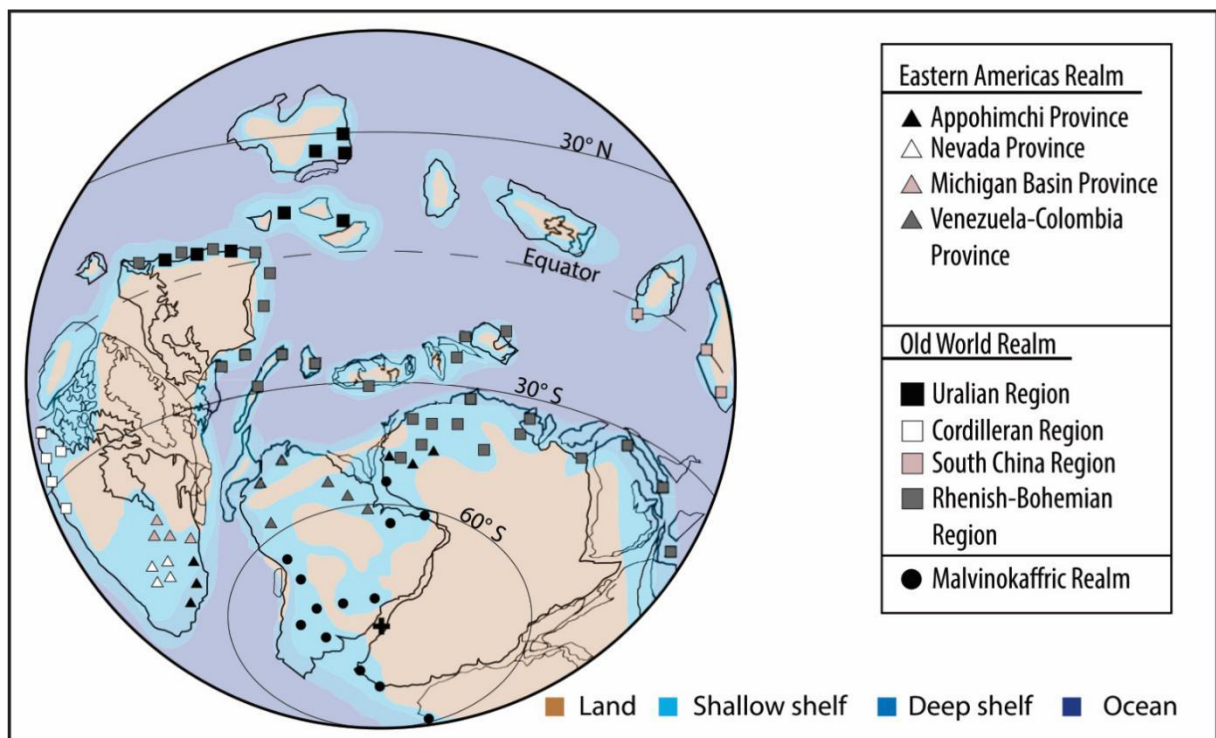


Figura 16- Paleobiogeografia do período Devoniano com base em Boucot (1988), Torsvik & Cocks (2011, 2013) e Boucot *et al.* (2013). Fonte do mapa: Penn-Clarke & Harper (2020).

Os limites geográficos dos reinos Malvinocáfrico e Américas Orientais são representados por zonas de mistura, onde ocorreram intercâmbios faunísticos, evidenciados no noroeste de Gondwana (Penn-Clarke & Harper 2020). Essa fronteira é traçada entre a Bolívia e o Peru, passando pelo Brasil, entre as bacias do Parecis e Amazonas, e pela Bacia do Parnaíba (Boucot 1988, Melo 1988, Boucot *et al.* 2001). A fauna mista Malvinocáfrica-Américas Orientais da Bacia do Parnaíba e da Bacia do Amazonas, com predominância de elementos das Américas Orientais, corrobora para o posicionamento dessas fronteiras no noroeste de

Gondwana (Carvalho 1975, Melo 1988, Fonseca 2001, 2004, Fonseca & Machado 2002, Gama 2008, Fonseca & Ponciano 2011, Penn-Clarke & Harper 2020).

No Devoniano, a biorregionalização ganhou maior evidência durante o final do Lochkoviano (Figura 17A), continuando no Praguiano e chegando ao seu ápice no Emsiano (Boucot *et al.* 1969, Johnson *et al.* 1973, Boucot 1988, Boucot & Blodgett 2001, Dowding & Ebach 2018). Essa tendência de expansão de biorregionalização durante o intervalo Lochkoviano-Emsiano coincide com o aumento na abundância de gêneros de braquiópodes neste mesmo intervalo (Figura 17B) (Williams *et al.* 2007).

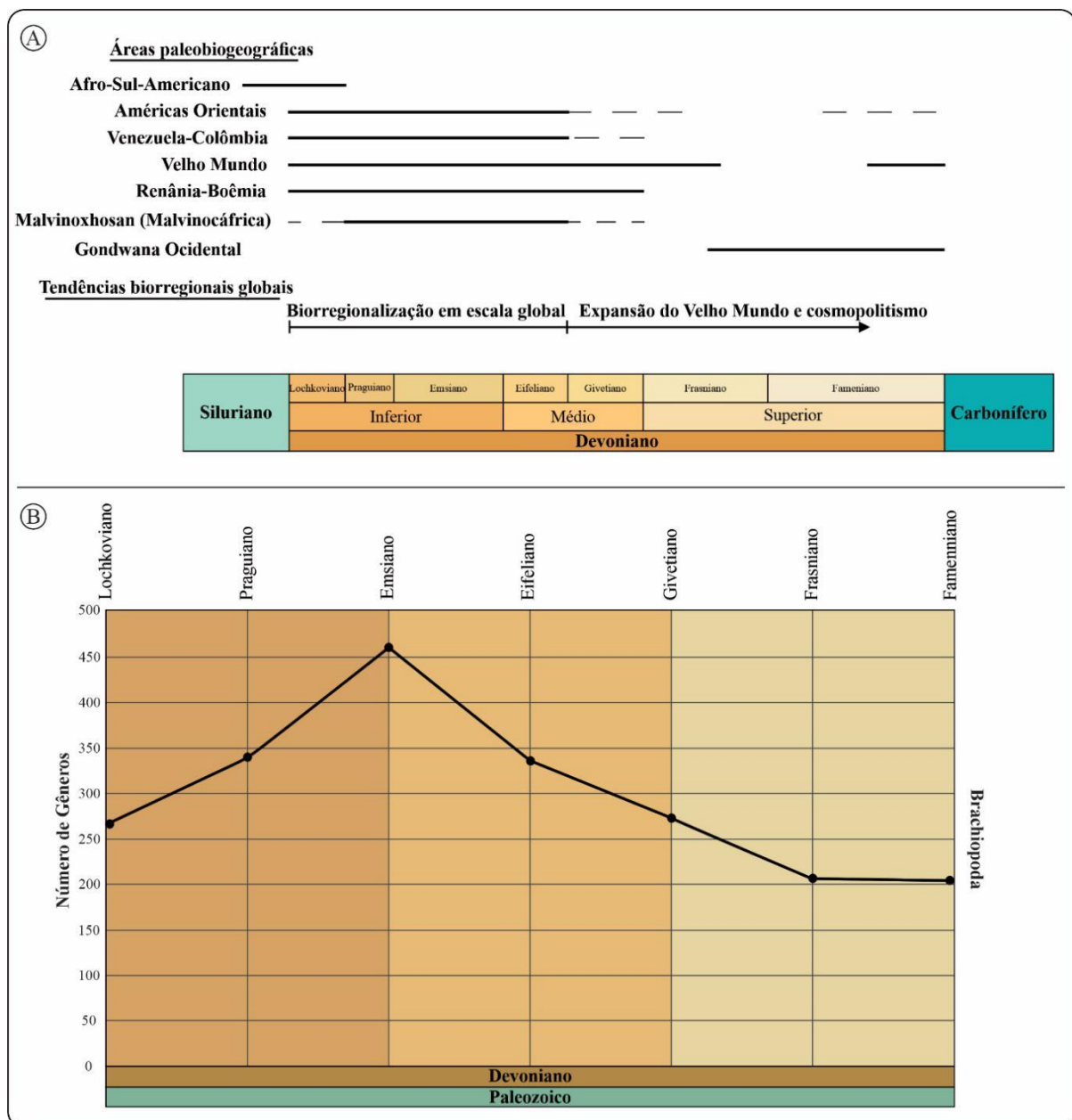


Figura 17- A) áreas biogeográficas ao longo do Devoniano; B) número de gêneros de braquiópodes ao longo do Devoniano. Fonte: A) Penn-Clarke & Harper (2020); B) Williams *et al.* (2007).

Durante o Givetiano, as áreas biogeográficas foram reduzidas, as faunas endêmicas já não prevaleciam. Os organismos do Reino do Velho Mundo se expandiram para regiões antes abrangidas pelos reinos das Américas Orientais e Malvinocáfrico (Boucot *et al.* 1969, 2001, Johnson *et al.* 1973, Boucot 1988, Boucot & Blodgett 2001, Penn-Clarke *et al.* 2018, Penn-Clarke 2019). O Reino Malvinocáfrico entrou em colapso e desapareceu, provavelmente devido ao aumento das temperaturas e a uma grande transgressão que possivelmente começou no final do Eifeliano, colaborando para a quebra das barreiras térmicas entre as regiões de alta e baixa latitude (Penn-Clarke 2019). Durante o Devoniano Superior apenas os reinos das Américas Orientais (reduzido) e do Velho Mundo (expandido) persistiram, além do surgimento do Reino Gondwana Ocidental durante o Frasniano (Dowding & Ebach 2018, 2019, Penn-Clarke & Harper 2020).

Penn-Clarke & Harper (2020) propuseram uma nova biorregionalização para o Oeste de Gondwana durante o intervalo Praguiano – Eifeliano, com base na distribuição dos braquiópodes. Duas áreas de primeira ordem foram identificadas: as biorregiões “Latitude temperada” e “Alta latitude” (Figura 18). Dentre os três Reinos tradicionais (Américas Orientais, Velho Mundo e Malvinoxhosan) presentes no Oeste de Gondwana, apenas o Reino Malvinoxhosan é validado como uma única unidade biogeográfica, porém sua área é reduzida (excluindo Senegal, Guiné e Guiné-Bissau), e ele deixa de ser uma unidade de primeira ordem, passando para uma unidade de segunda ordem (Penn-Clarke & Harper 2020).

A biorregião “Latitude Temperada” abrange uma única área biogeográfica chamada de “Colombiano-Oeste Africano”, situada entre as latitudes 30°S – 60°S, que abrange Venezuela e Colômbia (Bacia de Llanos), Guiné, Guiné-Bissau e Senegal (Bacia de Bové), Norte do Saara (Bacias de Tindouf, Ghadamis, Polignac e Murzuq) e Sul do Saara (Bacia de Tamesna e Taoudeni) (Penn-Clarke & Harper 2020). A biorregião “Alta Latitude” é subdividida em duas regiões de segunda ordem: Amazônia e Malvinoxhosan (Penn-Clarke & Harper 2020).

A unidade Amazônia abrange as bacias do Amazonas e Parnaíba e possivelmente parte do Peru, restrita às latitudes 50°S – 60°S, sendo uma região intermediária entre as biorregiões Colombiano-Oeste Africana e Malvinoxhosan. A biorregião Malvinoxhosan ocorre entre as latitudes 60°S – 90°S, identificada na Bolívia (Bacia de Chaco), Brasil (bacias do Paraná e Parecis), Argentina (Precordillera), África do Sul (Bacia do Cabo) e Ilhas Malvinas (Fox Bay) (Penn-Clarke & Harper 2020). Uma subdivisão de terceira ordem provisória é proposta para a biorregião Malvinoxhosan, as unidades Paraná (80°S – 90°S) e Andeo-Sul-Africano (70°S – 80°S) (Penn-Clarke & Harper 2020). A biorregião Paraná é caracterizada por uma baixa diversidade de terebratulidas, productidas e orthotetidas, além da ausência de orthidas.

Penn-Clarke & Harper (2020) ressaltam que a biorregionalização no Oeste de Gondwana durante o Devoniano (Praguiano-Eifeliano) seguiu padrões latitudinais, cujas diferenças climáticas e a temperatura das águas dos oceanos foram fatores determinantes para a delimitação das áreas biogeográficas. A diversidade em nível de gênero também seguiu tais padrões, onde foi mais alta nas regiões mais a norte (biorregião Colombiano-Oeste Africano) e diminuindo em direção ao Polo Sul (biorregião Malvinoxhosan) (Penn-Clarke & Harper, 2020).

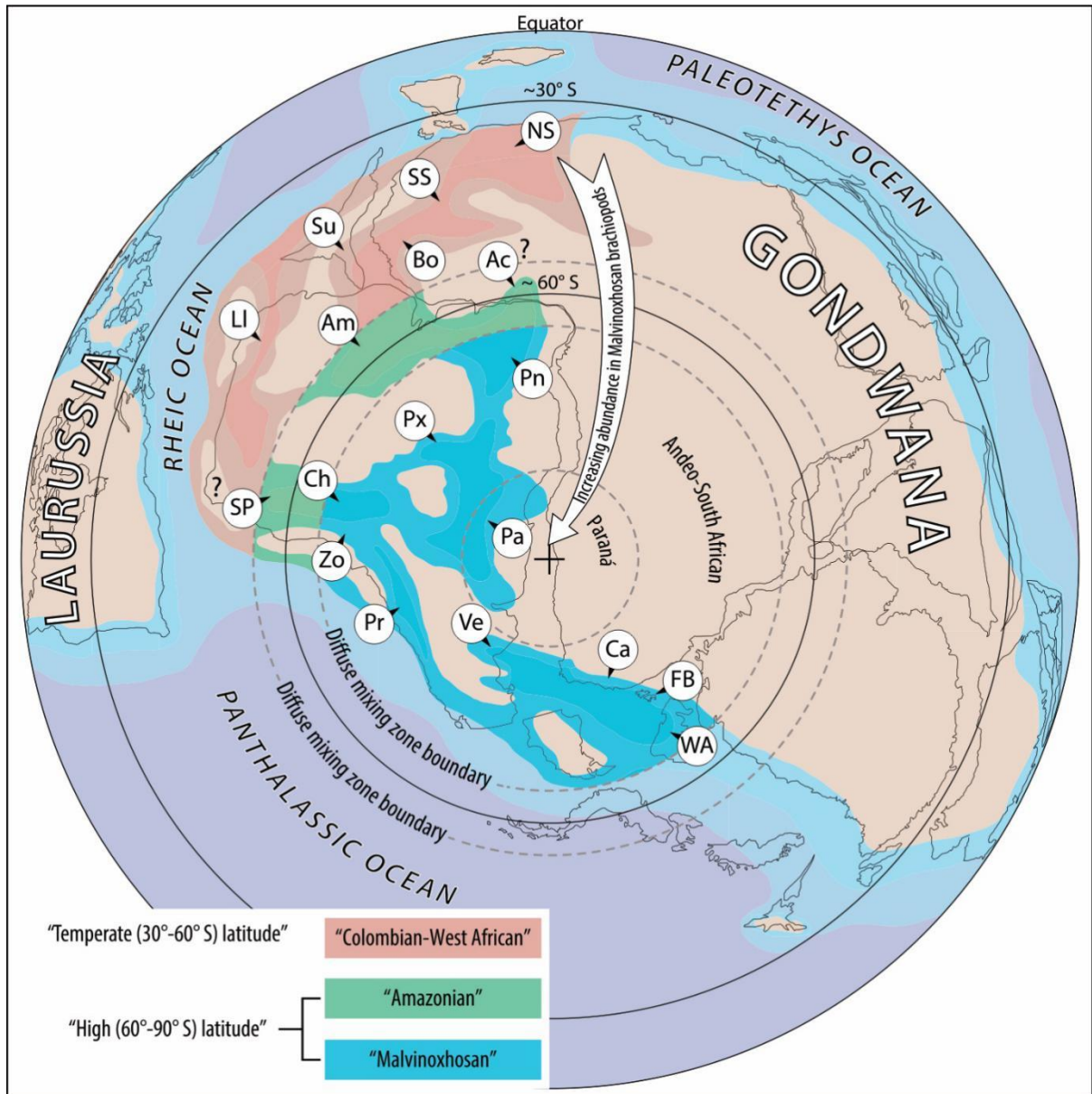


Figura 18- Biorregiões do Oeste de Gondwana durante o intervalo Praguiano-Eifeliano baseada na distribuição das faunas de braquiópodes. Fonte: Penn-Clarke & Harper (2020).

4.3 BRAQUIÓPODES DEVONIANOS DA BACIA DO AMAZONAS

A Bacia do Amazonas possui a maior diversidade de braquiópodes devonianos entre as bacias paleozoicas brasileiras (Paraná, Parecis, Parnaíba e Jatobá). As seções devonianas da

Bacia do Amazonas registram três classes, nove ordens, 24 famílias, 29 gêneros e 44 espécies de braquiópodes, distribuídos entre as formações Manacapuru, Maecuru, Ererê e Barreirinha (Tabela 3). Para as formações Jatapu e Curiri, não há registro de braquiópodes devonianos.

Tabela 3- Lista de braquiópodes devonianos da Bacia do Amazonas.

(continua)

Phylum Brachiopoda	Formações				Referências
	Manaca puru	Maecuru	Ererê	Barreirinha	
Classe lingulata					
Ordem Lingulida					
<i>Orbiculoidea baini</i>	X				Corrêa (2020)
<i>Orbiculoidea bodenbenderi</i>	X				
<i>Orbiculoidea excentrica</i>	X				
<i>Orbiculoidea</i> sp. 1	X				
<i>Orbiculoidea</i> sp. 2	X				
<i>Gigadiscina?</i> sp.	X				
<i>Orbiculoidea lodensis</i>				X	Rathbun (1878)
<i>Orbiculoidea</i> sp.			X		Fonseca & Ponciano (2011)
<i>Lingula erenrensis</i>			X		Rathbun (1878)
<i>Lingula spatulata</i>			X		Rathbun (1878)
<i>Lingula graçana</i>				X	
<i>Lingula rodriguezii</i>				X	
<i>Lingula stauntoniana</i>				X	
<i>Lingula</i> sp.	X				Grahn & Melo (1990)
<i>Schizobolus truncatus</i>				X	Clarke (1913)
Classe Rhynchonellata					
Ordem Orthida					
<i>Tropidoleptus carinatus</i>		X	X		Rathbun (1874)
<i>Discomyorthis hartti</i>		X			Carvalho (1975)
<i>Platyorthis nettoana</i>		X	X		
Ordem Terebratulida					
<i>Derbyina jamesiana</i>		X	X		Carvalho (1975)
<i>Paranaia wardiana</i>		X	X		
<i>Amphigenia elongata</i>		X			Rathbun (1878)
<i>Podolella rathbuni</i>		X			Copper (1977)
<i>Podolella derbyana</i>			X		Carvalho (1975)
Ordem Spiriferida					

(conclusão)

Phylum Brachiopoda Classe Rhynchonellata Ordem Spiriferida	Formações				Referências
	Manaca puru	Maecuru	Ererê	Barreirinha	
<i>Acrospirifer duodenaria</i>		X			Carvalho (1975)
<i>Acrospirifer buarquianus</i>		X			
<i>Mucrospirifer katzeri</i>		X			Clarke (1913)
<i>Mucrospirifer pedroanus</i>		X	X		Carvalho (1975)
<i>Plicoplasia curupira</i>		X	X	X	
<i>Australospirifer? lauro-sodreanus</i>		X			Katzer (1903)
<i>Spirifer buarquianus</i>		X			Rathbun (1878)
<i>Spirifer derby</i>		X			
<i>Spirifer hartii</i>		X			
<i>Spirifer</i> sp.		X		X	Macambira <i>et al.</i> (1977); Melo (1985)
Ordem Spiriferinida					
<i>Cyrtina? maecuruensis</i>		X			Clarke (1899)
Ordem Rhynchonellida					
<i>Camarotoechia? Aff. C. soppo</i>		X			Clarke (1913)
<i>Leptocoelia? sp</i>		X			Copper (1977)
<i>Rhynchonella ererensis</i>			X		Rathbun (1878)
Classe Strophomenata Ordem Strophomenida					
<i>Protileptostrophia</i> sp.		X			Carvalho (1975)
<i>Megastrophia hoeferi</i>		X			Carvalho (1972)
Ordem Productida					
<i>Chonetes freitasi</i>		X	X		Rathbun (1878)
<i>Chonetes hebert-smithi</i>		X	X		Rathbun (1874)
<i>Chonetes? curuaensis</i>		X			Rathbun (1878)
<i>Chonetes onettianus</i>			X		Rathbun (1874)
<i>Montsenetes carolinae</i>		X			Fonseca (2004)
<i>Pleurochonetes comstocki</i>		X	X		
<i>Productella maecuruensis</i>		X			Rathbun (1878)
<i>Anoplia nucleata</i>		X			Katzer (1933)
<i>Chonostrophia knodi</i>		X			Copper (1977)
Ordem Orthotetida					
<i>Schuchertella agassizi</i>		X	X		Rathbun (1874)
<i>Orthotetes agassizi</i>				X	Macambira <i>et al.</i> (1977)

4.3.1 Braquiópodes na Formação Manacapuru

A Formação Manacapuru carece de estudos paleontológicos, especialmente no que diz respeito à taxonomia e tafonomia. Grahn & Melo (1990) foram os primeiros autores a relatar a ocorrência de braquiópodes em camadas da Formação Manacapuru na borda sul da Bacia do Amazonas, mas sem quaisquer detalhes taxonômicos ou tafonômicos. Tomassi *et al.* (2015) fizeram um relatório preliminar sobre um grande número de braquiópodes rhynchonellata e lingulata coletados em camadas correspondentes à porção superior da Formação Manacapuru, destacando a necessidade de estudos taxonômicos aprofundados.

O primeiro estudo taxonômico sobre os braquiópodes da Formação Manacapuru coletados em Belo Monte foi publicado por Corrêa (2020), com foco na identificação taxonômica de braquiópodes inarticulados da Família Discinidae. Três espécies de *Orbiculoidea* (*Orbiculoidea baini*, *Orbiculoidea bodenbenderi* e *Orbiculoidea excentrica*) foram registradas pela primeira vez na Bacia do Amazonas, além de três espécies que ficaram com sua classificação em aberto, *Orbiculoidea* sp. 1, *Orbiculoidea* sp. 2 e *Gigadiscina?* sp. O registro de *Orbiculoidea baini*, *Orbiculoidea bodenbenderi* e *Orbiculoidea excentrica* em camadas da Formação Manacapuru (Lochkoviano) são os mais antigos para a América do Sul.

4.3.2 Braquiópodes na Formação Maecuru

Em 1876, Orville Adalbert Derby fez o primeiro registro de braquiópodes da Formação Maecuru, em arenitos situados nas margens dos rios Maecuru e Curuá (Derby 1877). Um estudo taxonômico mais profundo foi realizado por Rathbun (1878), que identificou 21 espécies, oito das quais são novas. Posteriormente, parte dos táxons identificados por Rathbun (1878), e material adicional adquirido nas décadas seguintes, foram revisados e estudados por vários pesquisadores, como Katzer (1897, 1903, 1933), Clarke (1899, 1913), Carvalho (1975), Melo (1985) e Fonseca (2004).

Carvalho (1975) revisou os braquiópodes das ordens Orthida, Strophomenida, Spiriferida e Terebratulida da Formação Maecuru, estudados primeiramente por Rathbun (1878) e Katzer (1897, 1903). Em seu trabalho, das 11 espécies identificadas, apenas *Tropidoleptus carinatus* e *Amphigenia elongata* mantiveram a classificação original, enquanto as outras nove espécies foram reclassificadas como: *Discomyorthis hatti*, *Platyorthis nettoana*, *Protoleptostrophia* sp., *Megastrophia hoeferi*, *Acrospirifer duodenaria*, *Acrospirifer buarquiana*, *Mucrospirifer pedroanus*, *Plicoplasia curupira*, *Derbyina jamesiana* e *Paranaia wardiana*.

Fonseca (2004) estudou a Ordem Chonetoidea das formações Maecuru e Ererê. O autor reclassificou *Chonetes comstockii* como *Pleurochonetes comstocki*. Além disso, Fonseca (2004) estabeleceu o diagnóstico de *Chonetes freitasi* Rathbun, 1878, designando seus lectótipos e paralectótipos. O autor também propôs uma nova espécie: *Montsenetes carolinae*.

Os dados paleoecológicos inferidos para a Formação Maecuru vêm de estudos de duas associações de invertebrados marinhos bentônicos *Schuchertella agassizi* – *Ptychopteria eschwegei* e *Mucrospirifer katzeri* – *Ptychopteria eschwegei* (Ponciano & Machado 2007a, Ponciano *et al.* 2007). O primeiro é o único a apresentar braquiópodes, representados por 12 espécies, que correspondem a 44% dos indivíduos da associação, seguidos por 20 espécies de bivalves, 14 de gastrópodes, 12 de trilobitas, três de crinoides e três de tentaculites (Ponciano & Machado 2007a). As análises semiquantitativas e morfofuncionais permitiram inferir que o paleoambiente era marinho raso, com águas agitadas, bem oxigenadas, temperadas e com salinidade normal (Ponciano & Machado 2007a).

Os grandes blocos fossilíferos coletados na Expedição Orville A. Derby foram deslocados de seu local de origem sem uma análise tafonômica adequada (Fonseca & Ponciano 2011). O material das Expedições Morgan e da Comissão Geológica Imperial do Brasil não foram coletados seguindo o modelo padrão para análise tafonômica, o que pode resultar em interpretações tafonômicas equivocadas.

Os braquiópodes da Formação Maecuru ocorrem na porção superior da unidade, datada como Eifeliano através de estudos bioestratigráficos de miósporos e quitinozoários (Melo & Loboziak 2003, Grahn & Melo 2004, Fonseca & Ponciano 2011).

Durante o Devoniano Médio, a Bacia do Amazonas estava situada em uma região de fronteira paleobiogeográfica, o que provavelmente explica a mistura de elementos faunísticos do Velho Mundo, Américas Orientais e reinos Malvinocáfricos (Melo 1985, Fonseca & Ponciano 2011). Entre os braquiópodes, há predominância dos gêneros com afinidade ao reino das Américas Orientais (11 gêneros), ocorrendo também elementos dos reinos do Velho Mundo (oito gêneros) e Malvinocáfrico (quatro gêneros). Para Boucot (1988), os braquiópodes da Formação Maecuru fazem parte da subprovíncia Amazônica-Colombiana.

Os seguintes táxons listados aqui têm identificações questionáveis e requerem revisão: *Podolella rathbuni*, *Mucrospirifer katzeri*, *Australospirifer? lauro-sodreanus*, *Spirifer buarquianus*, *Spirifer derbyi*, *Spirifer hartti*, *Spirifer sp.*, *Cyrtina? maecuruensis*, *Camarotoechia? Aff. C. soppho*, *Leptocoelia? sp.*, *Chonetes hebert-smithi*, *Chonetes? curuaensis*, *Productella maecuruensis*, *Anoplia nucleata*, *Chonostrophia knodi* e *Schuchertella agassizi* (Melo 1985, Fonseca & Ponciano 2011).

4.3.3 Braquiópodes na Formação Ererê

Os braquiópodes da Formação Ererê ocorrem na porção inferior da unidade, que corresponde ao Eifeliano (Melo & Loboziak 2003, Grahn & Melo 2004, Fonseca & Ponciano 2011). Diferentemente dos braquiópodes da Formação Maecuru (que apresentam maior diversidade), os táxons da Formação Ererê foram quase todos revisados por Carvalho (1975), Melo (1985) e Fonseca (2004).

No trabalho de Carvalho (1975), seis espécies anteriormente propostas por Rathbun (1874) foram reclassificadas (*Platyorthis nettoana*, *Mucrospirifer pedroanus*, *Plicoplasia curupira*, *Derbyina jamesiana*, *Paranaia wardiana* e *Podolella derbyana*), e apenas *Tropidoleptus carinatus* permaneceu com a classificação original.

Os braquiópodes da Família Chonetidae da Formação Ererê apresentam inconsistência em sua classificação sistemática devido à má preservação, que oculta as características diagnósticas. Rathbun (1874) fez o primeiro registro desta família, que foi posteriormente revisado por Clarke (1899), Katzer (1933), Kegel (1953) e Melo (1985), sendo que nunca houve um consenso quanto à classificação. O último trabalho de revisão foi desenvolvido por Fonseca (2004), no qual *Chonetes comstockii* foi reclassificada como *Pleurochonetes comstocki*. As espécies classificadas por Rathbun (1874) como *Chonetes herbert-smithii* e *Chonetes onettianus* não apresentam bom estado de conservação, o que impossibilita uma descrição detalhada do material, levantando dúvidas sobre sua classificação em nível de gênero (Fonseca & Ponciano 2011). A fauna de braquiópodes da Formação Ererê inclui *Schuchertella agassizi*, *Chonetes freitasi*, *Rhynchonella ererensis*, *Orbiculoidea* sp, *Lingula erenrensis* e *Lingula spatulata*.

4.3.4 Braquiópodes na Formação Barreirinha

Os braquiópodes da Formação Barreirinha ocorrem em camadas de folhelho negro, de idade Frasniano (Melo 1985, Melo & Loboziak 2003). Rathbun (1874) descreveu as espécies *Lingula graçana*, *Lingula stauntoniana*, *Lingula rodriguezii*, *Orbiculoidea lodensis* e *Vitulina pustulosa* a partir de camadas de folhelho negro da Formação Barreirinha. O autor relatou limitações na identificação do material e concluiu que a fauna da região do Ererê é semelhante à fauna registrada no Grupo Hamilton de Nova York. Posteriormente, Carvalho (1975) reclassificou *Vitulina pustulosa* como *Plicoplasia curupira*.

Clarke (1913) analisou material fornecido pelo Dr. Israel Charles White (Chefe da Comissão do Carvão), também coletado no folhelho negro da região do Ererê, e identificou o *Schizobolus truncatus*. Clarke foi um dos pioneiros a considerar a possibilidade de que esta

camada representasse o primeiro registro do Devoniano Superior na América do Sul. Mais tarde, Macambira *et al.* (1977) mencionaram a ocorrência de *Orthotetes agassizi* e *Spirifer* sp. em uma camada de folhelho preto atribuída ao antigo Membro Barreirinha, na região de Altamira, Estado do Pará.

A fauna da Formação Barreirinha não possui elementos da província ou domínio paleobiogeográfico do Devoniano. Os braquiópodes inarticulados *Orbiculoidea lodensis* e *Schizobolus truncatus* da Formação Barreirinha são duvidosamente correlacionados com os *Orbiculoidea* do folhelho Geneseo (Frasniano, leste dos EUA) (Melo 1985).

CAPÍTULO 5 DISCINOIDS (BRACHIOPODA: LINGULATA) FROM THE UPPER MANACAPURU FORMATION (EARLY DEVONIAN), SOUTH BORDER OF AMAZONAS BASIN, BRAZIL

Luiz Felipe Aquino Corrêa ^{a,*}, Maria Inês Feijó Ramos ^b

^a Universidade Federal do Pará, Rua Augusto Corrêa, 1 - Guamá, 66075-110, Belém-PA, Brazil.

^b Museu Paraense Emílio Goeldi, Coordenação de Ciências da Terra, Av. Perimetral, 1901 - Terra Firme, 66077-830, Belém-PA, Brazil.

Artigo publicado em **Journal of South American Earth Sciences** 105 (2021): 102960

Highlights

1. The taxonomical study, allowed to recognize *Orbiculoidea baini*, *O. bodenbenderi*, *O. excentrica*, *O. xinguensis* sp. nov. and *O. katzeri* sp. nov.
2. These are the first records of the species *O. baini*, *O. bodenbenderi*, and *O. excentrica* in the Manacapuru Formation.
3. The record of these discinoids is essential for the evolutionary understanding of these organisms during the Devonian in South America.

ABSTRACT

The taxonomic study of brachiopods (Family Discinidae) from the upper part of the Manacapuru Formation (Lochkovian), south border of the Amazonas Basin, Brazil, allowed to recognize five species of *Orbiculoidea*: *O. baini*, *O. bodenbenderi*, *O. excentrica*, and two new species described herein: *O. xinguensis* sp. nov. and *O. katzeri* sp. nov. Besides, *O. baini*, *O. bodenbenderi*, and *O. excentrica* are recorded for the first time in the Manacapuru Formation, and in Northern Brazil, being the oldest records (Lochkovian) of these species in South America too. Their presence in the region can be explained by two reasons: the proximity of the Amazonas Basin, located in northwest Gondwana, during the Early Devonian to the continent of Laurasia (where are recorded most occurrences of *Orbiculoidea* during the Silurian), favoring the specific interchange between these two geographic regions; and the global sea level rise during this time, which flooded a large part of northwestern Gondwana, resulting in the presence of shallow seas in the Amazonas Basin, represented by marine sediments in the upper part of the Manacapuru Formation. These conditions promoted the colonization of inarticulate brachiopods during the Early Devonian in the north of Brazil. The discinoids

identified in the strata of the Manacapuru Formation are typical of shallow marine environments, supporting previous interpretations for the upper part of this unit.

Keywords: *Orbiculoidea*. Lochkovian. Amazonas Basin. Gondwana.

5.1 INTRODUCTION

Discinoids are inarticulate brachiopods with organophosphate valves, predominantly marine, that emerged in the Cambrian. Presently, they include four genera, whose distribution is mainly controlled by environmental factors (Emig 1997, Holmer & Popov 2000, Zhang *et al.* 2018). They are important tools for Paleozoic paleobiogeographic studies, which increased in the 21th century (Popov *et al.* 2013, Winrow & Suttont 2014, Zhang *et al.* 2018, Zabini *et al.* 2019).

Its occurrence in the Ordovician is rare, restricted to low latitudes (Zhang *et al.* 2018). The Ordovician was marked by global climate changes and the geographical configurations of continental masses, contributing to the Hirnantian Glaciation (Late Ordovician – Early Silurian) that persisted for almost 35 million years (Finnegan *et al.* 2011). During this time, climatic conditions were quite severe in Gondwana, recording the persistence of only a few discinoids, such as *Kosoidea australis* from the Iapó and Vila Maria formations, Parana Basin (Zabini *et al.* 2019). During the transition from the Silurian to the Devonian, the melting of the polar ice caps that covered part of Africa and South America resulted in the maximum marine transgressions covering a large part of the supercontinent Gondwana, mainly the northwest portion (Bolivia, Brazil, Falkland Islands, South Africa, and Australia) (Ludwig 1964, Carozzi *et al.* 1973, Caputo 1984, Caputo & Crowell 1985, Grahn & Caputo 1992, Cunha *et al.* 1994). Such conditions were fundamental for a significant paleogeographic distribution of the brachiopods during the Devonian.

Despite this radiation, the reports of this group are scarce in South America, mainly in the Amazonas and Parnaíba basins. Previous occurrences have been mentioned, although only at a high taxonomic level, such as the records from strata of the Manacapuru (Pridoli-Lochkovian of the Amazonas Basin), Ererê (Eifelian-Givetian of the Amazonas Basin) and Pimenteiras formations (Eifelian-Frasnian of the Parnaíba Basin) (Grahn & Melo 1990, Wanderley Filho *et al.* 2005, Fonseca & Ponciano 2011, Ponciano *et al.* 2012).

By contrast, in the Parana Basin the discinoids are well known, mainly in the Devonian marine deposits of Ponta Grossa and São Domingos formations, where five species were recorded: *Orbiculoidea baini* Sharpe, 1856; *O. bodenbenderi* Clarke, 1913; *O. excentrica*

Lange, 1943; *Gigadiscina collis* Clarke, 1913, and *Rugadiscina stagona* Commiskey & Bosetti, 2017 (Clarke 1913, Lange 1943, Zabini *et al.* 2013, Commiskey *et al.* 2016, Commiskey & Bosetti 2017). The absence of taxonomic research on discinoids in the Amazonas and Parnaíba basins hinder the evolutionary understanding of these organisms during the Devonian in Brazil.

This work aims to study the taxonomy of the brachiopods of the family Discinidae found in strata of the Manacapuru Formation (municipality of Vitoria do Xingu), southern border of the Amazonas Basin, contributing to the evolutionary context of this group and enabling correlations at global level.

5.2 MATERIAL AND METHODS

The studied material consists of 272 brachiopod specimens, collected by the TERRAGRAPH PALEONTOLOGIA team between July 2011 and October 2015, in the frame of the project entitled “Paleontological Heritage Rescue Program” of the Belo Monte Hydroelectric Plant, municipality of Vitoria do Xingu, State of Para. Four sampling sites were analyzed: C3P1 (9653975 m N, 413823 m L, zone 22M, SAD 69), C9P1 (9655000 m N, 413261 m L, zone 22M, SAD 69), C13P1 (9653898 m N, 414191 m L, zone 22M, SAD 69), and C14P1 (9648213 m N, 406654 m L, zone 22M, SAD 69) (Figure 19).

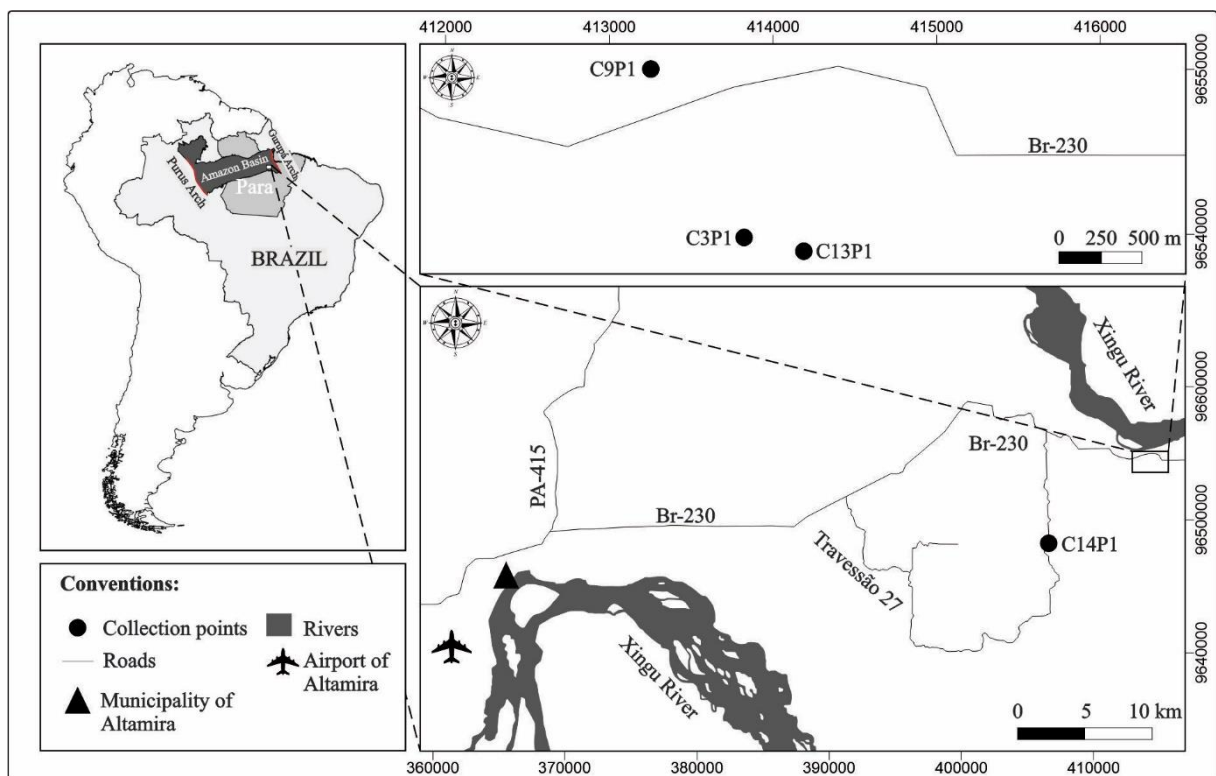


Figure 19- Location of the study area. Source: author.

The samples were collected according to the standard methods in paleontology, described in Tomassi *et al.* (2015a), and referred to the stratigraphic columns. For each specimen an individual number was assigned, with the following pattern: CmPn-X.Y, where Cm corresponds to the collection campaign (C1, C2, C3, ...), Pn is the geographical point within the campaign (P1, P2, P3, ...), X indicates the position in the stratigraphic column, Y is the sequential number of the sample (1,2,3, ...). Figured specimens are housed in the paleontological collection at Museum Paraense Emílio Goeldi, Belém, Pará, under catalogue numbers MPEG-3655 to MPEG-3927.

Photographs were taken with a high-resolution digital camera (Canon Powershot A640) attached to an electronic magnifying glass (LEICA M205 A) and the image capture system. Three valves were extracted from the rock samples (MPEG-3726, MPEG-3728, and MPEG-3746) for being photographed in the scanning electron microscope (SEM) of the research campus of the Museum Paraense Emílio Goeldi. The measures of length (L) and width (W) were obtained with a micrometric lattice of the magnifying glass (LEICA S8AP0).

The taxonomic classification follows Holmer and Popov (2000) for families and genera. Regarding species, the main pertinent articles were consulted: Sharpe (1856), Clarke (1913), Lange (1943), Comniskey & Bosetti (2017), and Carbonaro *et al.* (2018).

5.3 GEOLOGICAL SETTING

The Amazonas Basin is limited to the east by the Gurupa Arch, from the Marajo Basin, and to the west by the Purus Arch from the Solimões Basin (Cunha *et al.* 2007). It is located in the South American platform, covering an area of about 500.000 km² in the States of Amapá, Amazonas, and Pará, north of Brazil (Cunha *et al.* 1994). This basin is classified as an intracratonic “Type I - Simple Interior” (Klemme 1980). Its origin has been associated with the dispersion of North-South direction efforts, referring to the closing of the Brazilian cycle (Cunha *et al.* 2007). After the distensive processes, the magmatic bodies cooled down, initiating the regional thermal subsidence and the emergence of an intracontinental syneclysis. This process formed a basin with elongated geometry, predominantly filled by siliciclastic rocks, essentially Paleozoic, intruded by Mesozoic dikes and diabase sills (Almeida 1967, Caputo 1984 Cunha *et al.* 2007).

According to Cunha *et al.* (2007), the current stratigraphic framework of the basin presents two first-order mega sequences, one Paleozoic and another Meso-Cenozoic. The Paleozoic mega-sequence is divided into four second-order sequences: Ordovician-Devonian, Devonian-Lower Mississippian, Middle Mississippian, and Pennsylvanian-Permian (Cunha *et al.* 2007). The Ordovician-Devonian sequence is represented by the Trombetas Group, recording the initial

deposition phase in the intracontinental syneclysis of the Amazonas Basin with characteristics of transgressive-regressive cycles (Ludwig 1964, Cunha *et al.* 1994). Overlaying the Arch of Purus, in the westernmost region of the basin, the strata reflect alternation of glacial and marine environments. In the eastern portion, sedimentation surpassed the Arch Gurupá, favoring the connection with northwest Africa (Cunha *et al.* 2007). The Trombetas Group (Ludwig 1964) was considered to be composed of the Autás-Mirim, Nhamundá, Pitinga, and Manacapuru formations (Cunha *et al.* 1994). Later, Cunha *et al.* (2007) proposed a new formation in the Trombetas Group, the Jatapu Formation, formerly the Jatapu Member of the Maecuru Formation (Urupadi Group).

The Manacapuru Formation (Caputo 1984) was first proposed as a member representing the upper part of the old “Trombetas Formation” (Caputo *et al.* 1971). It is characterized by fine to medium sandstones, neritic and coastal pelites, shales, and laminated siltstones, composing a transgressive-regressive sequence deposited in a deltaic system and shallow platforms (Carozzi *et al.* 1973, Caputo 1984, Cunha *et al.* 1994, Cunha *et al.* 2007, Souza & Nogueira 2009, Rocha *et al.* 2019). Biostratigraphic analyses performed by Grahn (2005) established a Pridoli – Lochkovian age for this unit. The fossiliferous content of the Manacapuru Formation includes brachiopods, conularids, fragments of eurypterids, ichnofossils, palynomorphs, and fishes (Lange 1967, Quadros 1985, Janvier & Melo 1988, Grahn & Melo 1990, Grahn & Paris 1992, Grahn 2005, Wanderley Filho *et al.* 2005, Steemans *et al.* 2008, Rocha *et al.* 2019).

5.4 RESULTS

Of the 272 brachiopods studied samples, 205 are discinoids, 57 are rhynchonelliforms, and 10 are lingulids. The focus of this research is the study of the linguliforms from the Manacapuru Formation belonging to the family Discinidae.

The four sampling sites (C3P1, C9P1, C13P1, and C14P1) were combined in a composite section (Figure 20), formed from base to top by a crystalline basement, followed by a 0.5 meters thick layer of fine-grained massive sandstone with discinoids, interspersed with clay lenses. Above, fine-grained sandstone with incipient lamination and discinoids arranged in almost the entire layer, followed by a laminated siltstone package about 2.1 meters in thickness, with discinoids concentrated at its base, always associated with rhynchonelliforms; on the top of the layer, only lingulids occur.

The lithological characteristic of the studied sequence shows that the discinoids occur predominantly in the shallower marine layers, represented by the sandstones of the base, characteristic of shoreface deposits. In addition, they also occur in more fine sediments in the subsequent the laminated siltstone layer, typical of offshore transitional deposits. It could

indicate that they were deposited under a lower energy than the previous one. The Manacapuru Formation is associated with a delta system in its lower part, whereas the shallow platform is recorded in the upper part (Carozzi *et al.* 1973, Cunha *et al.* 2007, Rocha *et al.* 2019).

According to the lithological characteristics as described above, and the information provided by Tomassi *et al.* (2015a) and Tomassi *et al.* (2015b), in addition to the fossiliferous association of typical marine brachiopods (Clarkson 1992, Holmer & Popov 2000), we locate the studied outcrops at the upper part of the Manacapuru Formation, attesting its typical shallow platform environment. According to the palynological analysis carried out by Grahn (2005) in the Belo Monte region, this portion is dated as Lochkovian.

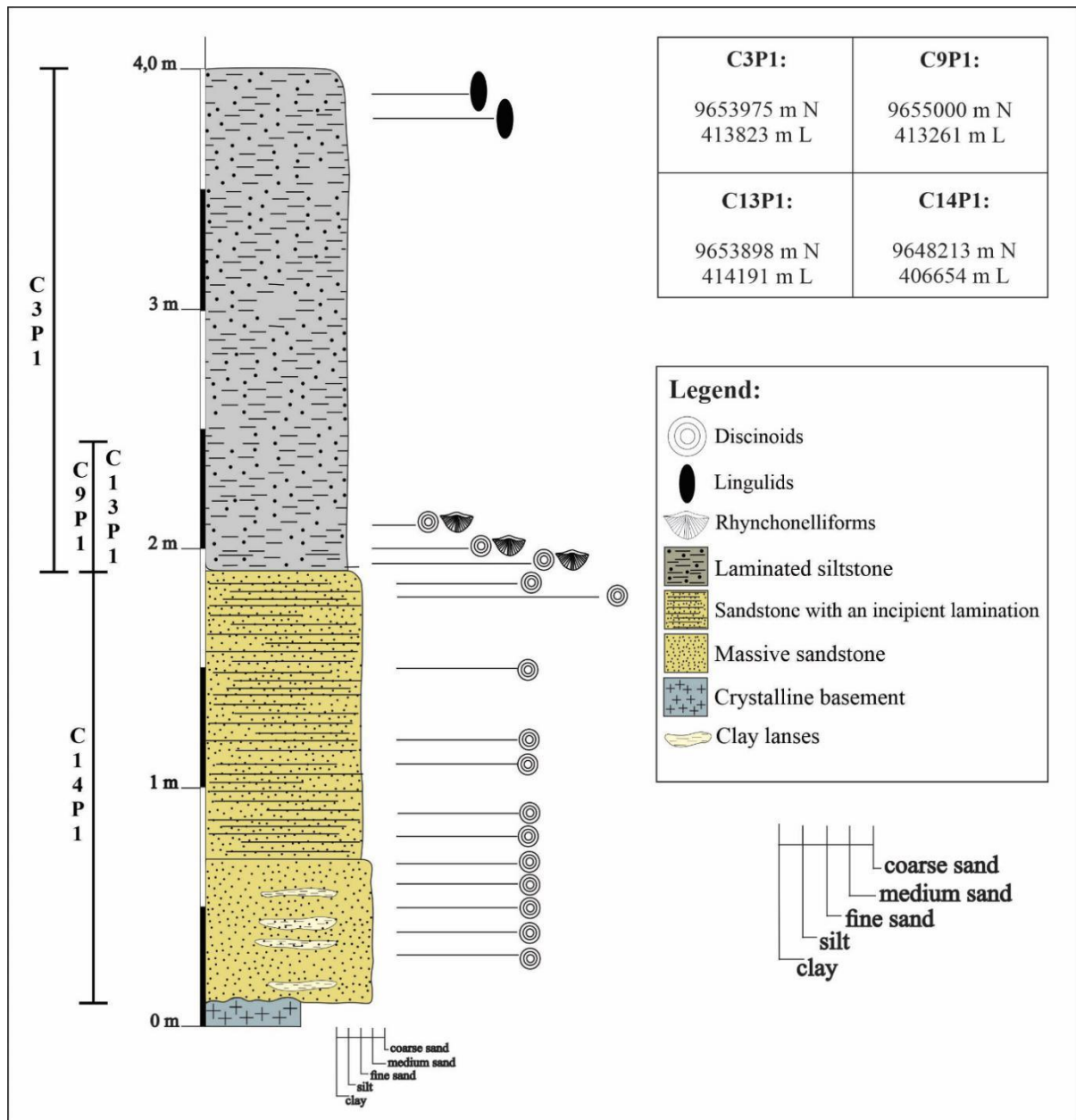


Figure 20- Composed stratigraphic section of the analyzed sample site. Source: author.

5.4.1 Systematic paleontology

Class Lingulata Gorjansky & Popov, 1985

Order Lingulida Waagen, 1885

Superfamily Discinoidea Gray, 1840

Family Discinidae Gray, 1840

Genus *Orbiculoidea* d'Orbigny, 1847

Type species - *Orbicula forbesii* Davidson, 1848

Orbiculoidea baini Sharpe, 1856
(Figure 21 A – D)

1856 *Orbicula bainii* Sharpe, p. 210, pl. 26, fig. 20–23.

1903 *Orbiculoidea baini* Sharpe — Reed, p.168, pl. 20, fig. 4–5.

1913 *Orbiculoidea baini* Sharpe — Clarke, p. 301, pl. 25, fig. 5–15.

1913 *Orbiculoidea baini* Sharpe — Kozłowski, p. 8-108, pl. 1, fig. 11–13.

1925 *Orbiculoidea (Roemerella) baini* Sharpe — Reed, p. 36–38, pl. IV, fig. 9-9a.

1954 *Orbiculoidea baini* Sharpe — Lange, p.33.

1967 *Orbiculoidea baini* Sharpe — Davila & Rodriguez, p. 921-935.

1971 *Orbiculoidea baini* Sharpe — Méndez-Alzola & Sprechmann, p. 517-525.

1985 *Orbiculoidea baini* Sharpe — Melo, p. 48a-57a.

1991 *Orbiculoidea baini* Sharpe — Figueiras, p. 57–64.

2001 *Orbiculoidea falklandensis* Sharpe — Boucot *et al.* p. 111, pl. 2, fig. 1–17.

2011 *Orbiculoidea baini* Sharpe — Comniskey, p. 54-58, pl. 4–7.

2016 *Orbiculoidea baini* Sharpe — Carbonaro & Ghilardi, p. 135-149, fig. 6K.

2017 *Orbiculoidea baini* Sharpe — Cominiskey & Bosetti, p. 175-192, fig. 3.3-3.4; 4.4-4.6.

2018 *Orbiculoidea baini* Sharpe — Carbonaro *et al.* p. 11-20, fig 3.

Description: The ventral valve is flat, with a circular outline, width similar to length. Dimensions vary between 9.2 mm - 14.9 mm in length and 9.7 mm - 15.1 mm in width. Rugellae well-marked, arranged concentrically around the apex. Valve flat with an apical region slightly depressed. Central apex with a smooth displacement towards the posterior region. The anterior region corresponds to approximately 60% of the valve. Between the posterior margin and the apex, it has on average between 15-17 well-marked rugellae, which thicknesses vary between 0.06 mm - 0.16 mm. The size of the interspaces between the growth lines has an almost imperceptible variation (0.18 mm - 0.24 mm). Well-marked pedicle track, triangular in shape,

starting behind the apical region and extending at least two-thirds of the length of the posterior region.

Occurrence: Sampling site C14P1, located at Sitio Belo Monte, municipality of Vitoria do Xingu, State of Para, Brazil. Manacapuru Formation (Lochkovian), Amazonas Basin.

Material: Ten ventral valves (MPEG- 3655 to MPEG-3664).

Remarks: The analyzed specimens show the diagnostic characteristics of the species, such as circular shell contour, well-marked rugellae, relatively large interspaces, eccentric apex, and well-marked pedicle track, similar to that was described by Sharpe (1856). The specimens of *Orbiculoidea baini* described by Clarke (1913), Lange (1954), Comniskey (2011), and Comniskey & Bosetti (2017) for the Devonian of the Parana Basin, differ in some aspects of the studied material, as they have more evident rugellae and larger pedicle track. The specimens analyzed in the present study are only larger than the specimens recorded by Comniskey *et al.* (2016), Comniskey & Bosetti (2017), and Carbonaro *et al.* (2018), that persisted after the lilliput effect (environmental stress), whose consequence is the decrease in the size of the species (phenotypes with maximum measures L: 7.0 W: 8.0).

Specimens from the Devonian of the Parana Basin have the pedicle track usually extended to the posterior margin; in the analyzed material only part of the pedicle track was preserved, which occupies about two-thirds of the length of the posterior region, making it difficult to compare with the other records in the literature. Boucot *et al.* (2001) described specimens from the Lower Devonian of the Parecis Basin, where the pedicle track is only one-third the length of the valve; despite this disparity, the authors choose not to propose a new species, justifying that such differences would be related to large-scale geographical variation, combined with others ecological aspects.

Geographic and stratigraphic distribution: South America: In Brazil, state of Paraná, Paraná Basin, Ponta Grossa and São Domingos formations (Pragian-Givetian) (Clarke 1913, Lange 1954, Comniskey & Bosetti, 2017); state of Goiás, Alto Garças Sub-Basin, Chapada Group Unit 4, (Givetian) (Carbonaro & Ghilardi 2016, Carbonaro *et al.* 2018), and state of Mato Grosso, Parecis Basin, Pragian (Boucot *et al.* 2001). In Argentina, Argentine Pre-Cordillera, Talacasto Formation (Pragian) (Méndez-Alzola & Sprechmann 1971); Bolivia, Pragian (Davila & Rodriguez 1967); Falkland Islands, Fox bay Formation, Pragian (Sharpe 1856), and Uruguay,

Chacoparanense Basin, Cordobes Formation (Pragian) (Figueiras 1991). Africa: South Africa, Bokkeveld Beds, Lower Devonian (Reed 1925).

Orbiculoidea bodenbenderi Clarke, 1913
(Figure 21 E – F)

1913 *Orbiculoidea bodenbenderi*, Clarke, p. 306, pl. 25, fig. 16-22.

1954 *Orbiculoidea bodenbenderi* Clarke — Lange, p. 41.

1985 *Orbiculoidea bodenbenderi* Clarke — Melo, p. 58a.

1991 *Orbiculoidea bodenbenderi* Clarke — Figueiras, p. 57 – 64.

2011 *Orbiculoidea bodenbenderi* Clarke — Comniskey, p. 59-62, pl. 8-10.

2017 *Orbiculoidea bodenbenderi* Clarke — Comniskey & Bosetti, p. 175-192, fig.3.7-3.8; 4.2; 4.7-4.9.

Description: The ventral valve is flat. Subcircular shell, 16.7 mm long and 16.3 mm wide; thinning in the contour of the posterior margin concerning the anterior margin; subcentral apex slightly shifted to the posterior margin; distance between the apex and the anterior margin is 11.8 mm, corresponding to approximately 70% of the total length of the valve; roughly evidenced rugellae, with thicknesses of 0.3 mm between the left part of the posterior margin and the apex. About 16 rugellae occur in the anterior region, in an interval of 5 mm. The spacing between rugellae is small and regular and the distance between them is approximately 0.7 mm. Unpreserved pedicle track.

Occurrence: Sampling site C14P1, located at Sitio Belo Monte, municipality of Vitoria do Xingu, State of Para, Brazil. Manacapuru Formation (Lochkovian), Amazonas Basin.

Material: Five ventral valves (MPEG-3665 to MPEG-3669).

Remarks: Clarke (1913) carried out the first description and discussion of the species *Orbiculoidea bodenbenderi* but did not give a diagnosis. We adopted the diagnosis proposed by Comniskey & Bosetti (2017), amended with minor modifications taken from the description made by Clarke (1913).

Besides *Orbiculoidea bodenbenderi* has the highest number of rugellae among the species identified herein, it has the same morphological characteristics of the specimens described by Comniskey & Bosetti (2017). A break was observed extending from the apical region to the posterior margin (Figure 21 E), responsible for not preserving the pedicle track.

Orbiculoidea bodenbenderi differs from *O. baini* in its quite flat ventral valve, due to the thinning in the contour of the posterior margin concerning the anterior margin, and in the number of rugellae that is larger, less evident, and with shorter spacing. *O. bodenbenderi* differs from *O. excentrica* because rugellae has a regular spacing, the apex is subcentral, and the number of rugellae is equal in both the anterior and posterior regions; in *O. excentrica* the spacing of the rugellae is irregular, the apex is subcentral, and the number of rugellae is greater in the anterior region.

Geographic and stratigraphic distribution: South America: In Brazil, state of Parana, Parana Basin, Ponta Grossa Formation (Pragian-Eifelian) (Clarke 1913, Lange 1954, Comniskey & Bosetti 2017). Falkland Islands, Fox bay Formation, Pragian (Clarke 1913); Uruguay, Chacoparanense Basin, Cordobes Formation, Pragian (Figueiras 1991).

Orbiculoidea excentrica Lange, 1943
(Figure 21 G – L)

1943 *Orbiculoidea excentrica*, Lange, p.223, pl. 17, fig. 1.

1954 *Orbiculoidea excentrica* Lange — Lange, p. 41-81.

1985 *Orbiculoidea excentrica* Lange — Melo, p. 61, fig. 1.

2011 *Orbiculoidea excentrica* Lange — Comniskey, p. 63-65, pl.11.

2016 *Orbiculoidea excentrica* Lange — Carbonaro & Ghilardi, p. 135-149, fig.6L.

2017 *Orbiculoidea excentrica* Lange — Comniskey & Bosetti, p. 175-192, fig. 3.5-3.6; 4.1

2018 *Orbiculoidea excentrica* Lange — Carbonaro *et al.* p. 11-20, figs. 3C-3D.

Description: Dorsal valve concave, subcircular in the outline. Posterior margin more acuminate than anterior margin. Dimensions vary between 3.2 mm - 9.9 mm in length and 3.6 mm - 10.1 mm in width. Umbo elevated and conical. Inclination angle starts in the anterior margin towards the apex and is smaller when compared with the posterior region. Slope smoothly convex in the anterior region, and concave in the posterior region. Apex is submarginal, located near the posterior margin; the distance between the apex and the posterior margin of the dorsal valve is approximately 25% - 30% of the total length of the valve. The tip of the apex is prominent, with a slight inclination towards the posterior margin. From the posterior margin towards the apex, it has an average of 19 rugellae, more concentrated in the anterior portion, generally seven more than the posterior part, with a thickness average of 0.02 mm - 0.06 mm. The interspaces between the rugellae are irregular, varying between 0.12 mm - 0.26 mm, with the spacing being larger in the anterior region. The ventral valve is flat,

subcircular in outline, and with a slight depression in the central portion. Submarginal apex displaced towards the posterior margin. Lirium present, covering completely the pedicle track.

Occurrence: Sampling sites C3P1, C9P1, C13P1, and C14P1, located at Sitio Belo Monte, municipality of Vitoria do Xingu, State of Para, Brazil. Manacapuru Formation (Lochkovian), Amazonas Basin.

Material: Forty-nine dorsal valves (MPEG-3670 to MPEG-3718) and three ventral valves (MPEG-3719 to MPEG-3721).

Remarks: Lange (1943) proposed this species based only on two specimens (ventral valves) and did not propose a diagnosis. Later, Comniskey (2011), Comniskey & Bosetti (2017), and Carbonaro *et al.* (2018), allowed a better comparison with the specimens studied herein. Then, we adopted the diagnosis of Comniskey & Bosetti (2017) adding an amendment including the characteristics proposed by Lange (1943).

The studied material presents the typical diagnostic characteristics of the species *Orbiculoidea excentrica*, such as submarginal apex, subcircular outline, great number of rugellae in the anterior region, and irregular spacing between them. However, the material described by Lange (1943) has almost twice rugellae in the anterior region, i.e., seven more rugellae in average than in the posterior region, when compared with the studied material. The distance from the apex to the posterior margin is very similar to the indicated by Lange (1943), and very close to the values stipulated by Carbonaro *et al.* (2018). The umbo is flatter and wider in some specimens (Figure 21 J), which can be attributed to compaction during the fossilization process, or to interspecific variation. *Orbiculoidea excentrica* differs from *O. baini* in to the irregular spacing of the rugellae, the submarginal apex, and the pedicle track restricted to the apical region.

Geographic and stratigraphic distribution: This species is restricted to Brazil occurring in the states of Parana, Parana Basin, Ponta Grossa and São Domingos formations (Pragian and Givetian) (Lange 1943, 1954, Comniskey & Bosetti 2017) and states of Goias, Alto Garças Sub-Basin, Chapada Group Unit 4, (Givetian) (Carbonaro & Ghilardi 2016, Carbonaro *et al.* 2018).

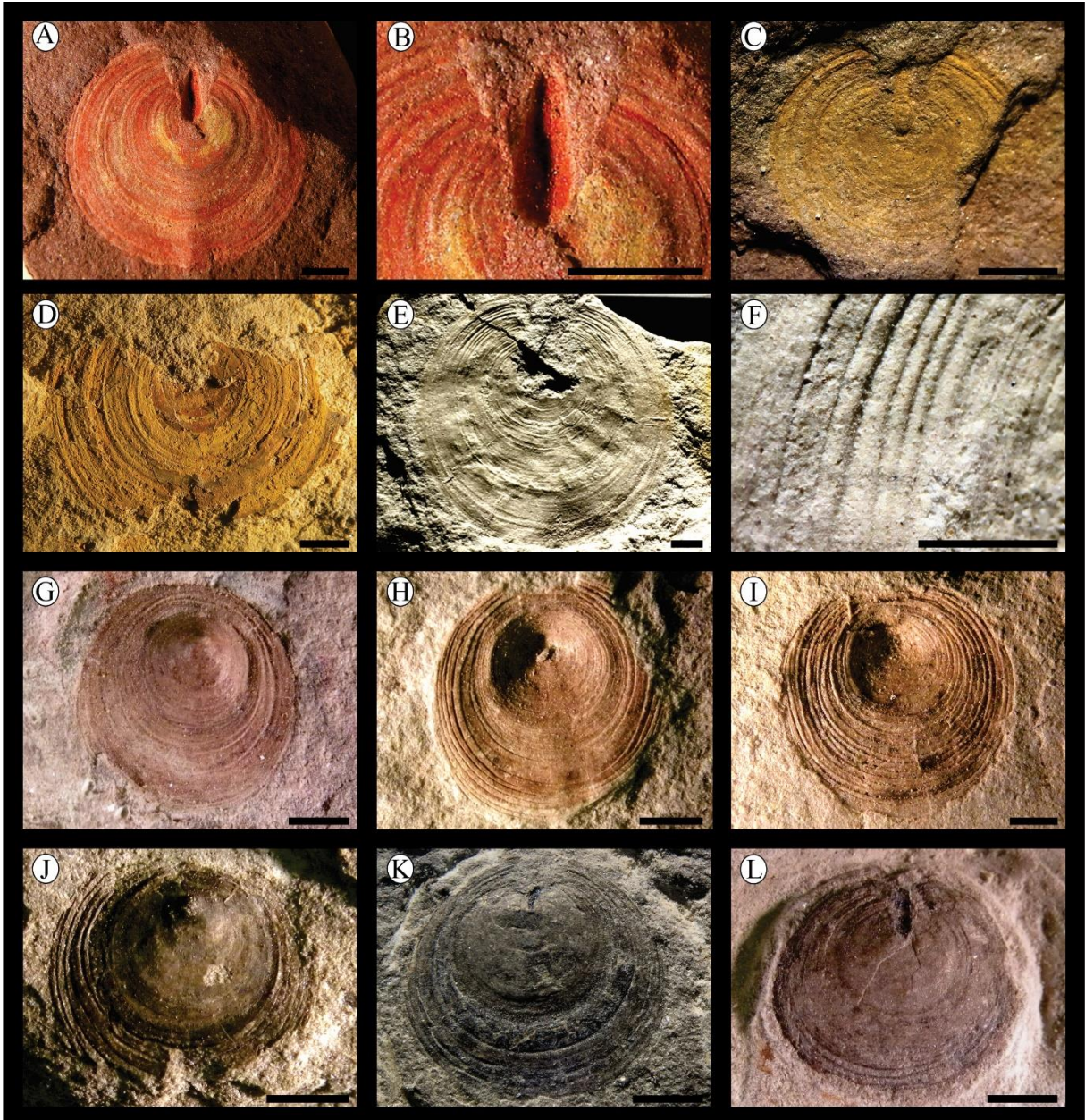


Figure 21- A – D: *Orbiculoidea baini* – A) MPEG- 3660 (ventral valve, internal mould), B) MPEG- 3660 (detail of the pedicle track), C) MPEG- 3657 (ventral valve, internal mould), and D) MPEG- 3662 (ventral valve, internal mould). E – F: *Orbiculoidea bodenbenderi* – E) MPEG-3668 (ventral valve, external mould) and F) MPEG-3668 (detail of the rugellae in posterior margin). G – L: *Orbiculoidea excentrica* – G) MPEG-3689 (dorsal valve, external mould), H) MPEG-3690 (dorsal valve, counter mold of MPEG-C9P1-4A), I) MPEG-3686 (dorsal valve, internal mould), J) MPEG-3672 (dorsal valve, internal mould), K) MPEG-3719 (ventral valve, internal mould), and L) MPEG-3720 (ventral valve, internal mould). Scale bar: 2 mm.

Orbiculoidea xinguensis sp. nov.
(Figure 22 A – E; figure 23 A – D)

Diagnosis: Convex flat shell, almost subtriangular in outline. The anterior margin is broader than the posterior margin. Dorsal valve high and convex, umbo well marked. Apex flattened, submarginal, displaced towards the posterior margin. The ventral valve is flat, with a slight

elevation in the umbo region. Lirium short, cylindrical, covering the pedicle track completely. Thin rugellae, with small and regular interspaces arranged in both valves.

Etymology: After “*xinguensis*”, referring to river Xingu, a famous river in the Amazon region, the main river of the studied area, Belo Monte.

Holotype: Dorsal valve (MPEG-3729).

Paratypes: Four dorsal valves (MPEG-3723, MPEG-3726, MPEG-3728, and MPEG-3735). One ventral valve (MPEG-3740).

Description: Shell subtriangular in outline. The dorsal valve is high, convex, and obtusely subconical. Dimensions vary between 9.2 mm - 17.8 mm in length and 8.8 mm - 18.1 mm in width. The apical region is well marked and elevated with a concave slope extending from the apex to the anterior margin. Apex flattened, slightly elevated, submarginal, displaced towards the posterior margin. On average, the anterior region corresponds to approximately 80% of the valve area. The rugellae are thin, well-marked, arranged concentrically around the apex. On the posterior margin towards the apex, it has an average of 22 rugellae, with small and regular interspaces. The ventral valve is flat, with a slight depression in the umbo region. Submarginal apex, displaced in the posterior direction. Umbo is well marked and flat. Well-marked rugellae, with regular interspaces. Pedicle track short and cylindrical.

Occurrence: Sampling sites C3P1, C13P1, and C14P1, located at Sitio Belo Monte, municipality of Vitoria do Xingu, State of Para, Brazil. Manacapuru Formation (Lochkovian), Amazonas Basin.

Material: Seventeen dorsal valves (MPEG-3722 to MPEG-3738) and four ventral valves (MPEG-3739 to MPEG-3742).

Remarks: The specimens described herein have morphological characteristics similar to the *Gigadiscina collis* ones described in Conniskey (2011) and Conniskey & Bosetti (2017), such as the subtriangular outline, thin rugellae with small spacing, and high dorsal valve. The microstructural analysis through electronic scanning microscope showed the absence of pores on the surface of both valves (Figure 23 C – D), a typical characteristic of the genus *Gigadiscina*. Besides, the analyzed specimens are very small when compared to *Gigadiscina*, when the large size of the valves was one of the main reasons for the creation of this genus.

Among the characteristics of *Orbiculoidea xinguensis* sp. nov., stands out the anterior margin, which is much larger than the posterior margin, resulting in a subtriangular outline, not common in *Orbiculoidea* species, in which predominate circular to subcircular outlines.

Orbiculoidea xinguensis sp. nov. differs from *O. baini* in its subtriangular outline, submarginal apex, and rugellae with smaller interspaces. It also differs from *O. bodenbenderi* in the submarginal apex, subtriangular outline, and by a slight depression in the central region of the ventral valve, whereas in *O. bodenbenderi* the apex is central to subcentral, subcircular outline, and flat ventral valve. It differs from *O. excentrica* due to its flatter apex, thinner rugellae with regular spacing; in *O. excentrica* the apex is conical and high, the rugellae are well marked and with irregular spacing.

Orbiculoidea katzeri sp. nov.
(Figure 22 F – I; figure 23 E – F)

Diagnosis: Subcircular shell, valve wider than long. Dorsal valve marginally flat, quite high and marked in the umbo region. Umbo high. Apex flattened, subcentral, slightly detached towards the posterior margin. Ventral valve flattened in the margins, with a slight elevation in the umbonal region. Listrium, robust, covering completely the pedicle track. Rugellae thin, with small and regular spacings.

Etymology: After “*katzeri*”, a tribute to geologist and paleontologist Friedrich Katzer, for his prominent contributions to paleontological studies in Amazonia during the 19th century.

Holotype: Dorsal valve (MPEG-3746).

Paratypes: Two dorsal valves (MPEG-3759 and MPEG-3758). One ventral valve (MPEG-3760).

Description: Dorsal valve convex and with subcircular outline. Dimensions vary between 9.6 mm - 19.8 mm in length and 10.1 mm - 19.8 mm in width. The width measurements are considerably larger when compared to the length measurements. Broad anterior margin. Rugellae well-marked. Apex robust, subcentral, slightly displaced towards the posterior margin. Umbonal region well marked and elevated, making the shell convex. Ventral valve flat, with a slight depression in the umbonal region, and subcircular outline. Apex flattened, subcentral, slightly displaced to the posterior margin. Umbonal region with a slight depression. Rugellae very evident, slightly accentuated, most notable in the lateral part of the posterior margin. Pedicle track robust, cylindrical in shape, starting from the apex to the posterior margin.

Occurrence: Sampling site C14P1, located at Sitio Belo Monte, municipality of Vitoria do Xingu, State of Para, Brazil. Manacapuru Formation (Lochkovian), Amazonas Basin.

Material: Seventeen dorsal valves (MPEG-3743 to MPEG-3759) and one ventral valve (MPEG-3760).

Remarks: Some characteristics are quite striking in the analyzed specimens, such as width, which is considerably greater than length, giving the impression that the contours of the valves are flattened, which differs from all the other species previously described, and the robust pedicle track, reaching the posterior margin.

Orbiculoidea katzeri sp. nov. differs from *O. baini* in the subcircular outline, more robust umbo, and rugellae with short spacing; in *O. baini* the outline is circular, the umbo is smaller and the spacing between the rugellae is larger. It differs from *O. excentrica* because of the umbo, which is robust and flattened, and the apex, which is subcentral, whereas in *O. excentrica* the umbo is smaller, the apex is conical, higher, and submarginal. It differs from *O. xinguensis* sp. nov. due to its subcircular outline and robust pedicle track, while in *Orbiculoidea xinguensis* sp. nov. the outline is subtriangular, and the pedicle track is small.

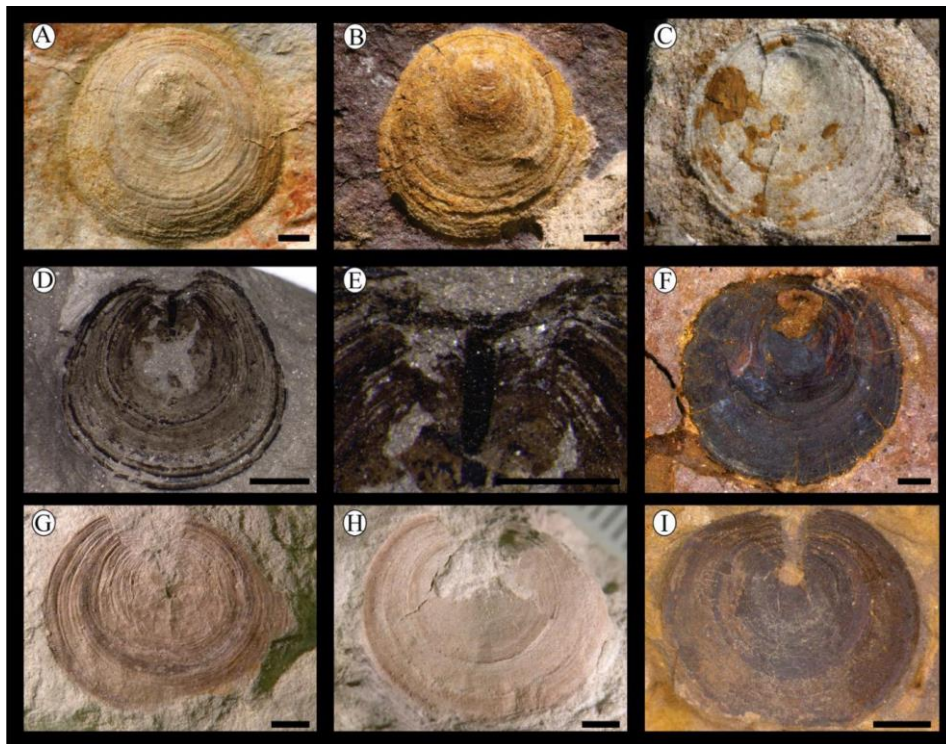


Figure 22- A – D: *Orbiculoidea xinguensis* sp. nov. – A) MPEG-3729 (dorsal valve, external mould), B) MPEG-3723 (dorsal valve, external mould), C) MPEG-3735 (dorsal valve, external mould), D) MPEG-3740 (ventral valve, internal mould), and E) MPEG-3740 (detail of the pedicle track). F – I: *Orbiculoidea katzeri* sp. nov. – F) MPEG-3746 (dorsal valve, internal mould), G) MPEG-3759 (dorsal valve, external mould), H) MPEG-3758 (dorsal valve, external mould), and I) B) MPEG-3760 (ventral valve, internal mould). Scale bar: A), B), C), D), F), G), H), and I): 2mm; E): 1mm.

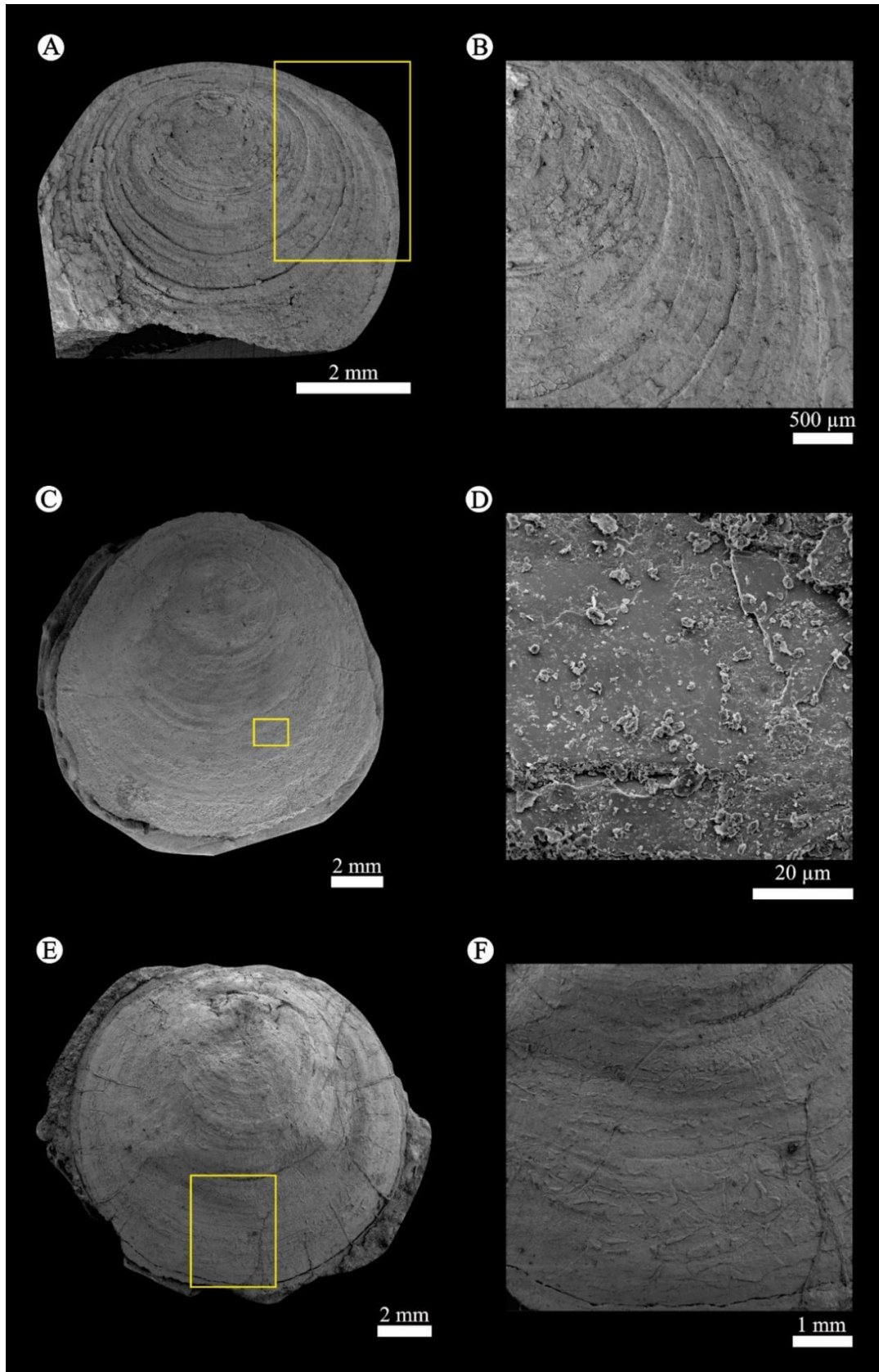


Figure 23- SEM images. A – D: *Orbiculoidea xinguensis* sp. nov. – A) MPEG-3726 (dorsal valve, external mould), B) MPEG-3726 (rugellae well-marked, with regular interspaces), C) MPEG-3728 (dorsal valve, external mould), and D) MPEG-3728 (absence of micro-ornamentation). E – F: *Orbiculoidea katzeri* sp. nov. – E) MPEG-3746 (dorsal valve, internal mould) and F) MPEG-3746 (absence of micro-ornamentation).

5.5 DISCUSSION

5.5.1 Paleocological aspects

Discinoids are brachiopods with two valves of organophosphate composition, predominantly marine, occurring in shoreface to offshore deposits (Holmer & Popov 2000, Comniskey *et al.* 2016). *Orbiculoidea* lived a mostly in the neritic zone (Zhang *et al.* 2018). The family Discinidae has different life habits, which brought up several discussions; more recent research suggests epibenthic habit (Südkamp 1997, Mergl 2001). The discinoids identified in the present work (*Orbiculoidea baini*, *O. bodenbenderi*, *O. excentrica*, *O. xinguensis* sp. nov., and *O. katzeri* sp. nov.) have flat or slightly arched ventral valves (described in the topic Paleontological Systematics), which indicates that they were attached to the substrate mainly by the pedicle, with an epibenthic habit (Mergl 2001).

The analyzed material consists mostly of disarticulated valves. According to Südkamp (1997), the fact that inarticulate brachiopods have both valves connected only by muscles explains why the valves are commonly preserved disarticulated.

Studies on the habits of living genera of the Superfamily Discinoidea (*Discina* Lamarck, 1819; *Discinisca* Dall, 1871; *Discradisca* Stenzel, 1964; *Pelagodiscus* Dall, 1908) are used as parameters to infer the life habits of fossil discinoids, even having a significant temporal distance (Zhang *et al.* 2018).

Orbiculoidea lived mostly in shallow coastal marine environments. This statement is suggested by the fact that the distribution of most recent discinoids occurs at depths less than 30 meters (Emig 1997, Zhang *et al.* 2018). According to Zhang *et al.* (2018), most *Orbiculoidea* fossil records (92.7%) indicate shallow marine conditions. The discinoid fauna recorded in the Devonian of the Parana Basin, is associated with platform marine deposits (Comniskey 2011, Comniskey *et al.* 2016, Comniskey & Bosetti 2017).

In the present study the *Orbiculoidea* species that occur in fine-grained massive sandstone interspersed with clay lenses, and in the fine-grained sandstone with incipient lamination, are associated with shoreface deposits. On the other hand, the discinoids that occur along with rhynchonelliforms in the base of the laminated siltstone are associated with offshore transitional deposits. Therefore, the presence of *Orbiculoidea* in the Manacapuru Formation suggests a shallow marine environment, corroborating previous studies concerning the upper part of this formation (Carozzi *et al.* 1973, Cunha *et al.* 2007, Rocha *et al.* 2019).

When analyzing the discinoids identified in the present research we realize that they have morphological characteristics of adult forms; however, when we compare their sizes with

the other records in the literature (Méndez-Alzola & Sprechmann 1971, Boucot *et al.* 2001, Comniskey & Bosetti, 2017), we note that they are relatively small. The exception are *O. baini* and *O. excentrica* specimens from the Givetian of the Unit 4 of the Alto das Garças Sub-basin (Parana Basin) and the Upper part of the São Domingos Formation, Parana Basin (Comniskey *et al.* 2016, Comniskey & Bosetti 2017, Carbonaro *et al.* 2018), whose reduced size is related to a global biotic crisis “Kačák”, which occurred in the transition Eifelian / Givetian (House 1996, 2002, Bosetti *et al.* 2010, Horodyski *et al.* 2014, Comniskey *et al.* 2016, Comniskey & Bosetti 2017).

According to Boucot *et al.* (2001) morphological variations among some species of *Orbiculoidea* would be related to geographical variation in large scale, combined with ecological factors. Chuang (1961) demonstrated the relationship between local environmental effects and the growth rate of lingulids. The fact that the registered fauna has small sizes may be linked to paleobiogeographic factors and consequently environmental changes (for more detail see discussion below in the Stratigraphic and paleobiogeographic distribution chapter).

5.5.2 Stratigraphic and paleobiogeographic distribution

Orbiculoidea has a wide geographical distribution (Africa, North America, South America, Antarctica, Asia, Europe, and Oceania) but a restricted stratigraphic range (Ordovician to Permian). The survey of its geographic occurrence allowed to verify that despite the presence of *Orbiculoidea baini* in Pragian strata of South Africa (Reed 1925), it has the widest geographic and stratigraphic distribution in South America (Figure 24). *Orbiculoidea bodenbenderi* is registered only in South America, in the Pragian to Eifelian interval, whereas *O. excentrica* is registered only in Brazil, occurring in the Pragian to Emsian of the Paraná Basin. During the Eifelian there is no record of *O. excentrica*; however, it is recorded in the Givetian of the Paraná Basin and Alto das Garças sub-basin.

The record of the species *Orbiculoidea baini*, *O. bodenbenderi*, and *O. excentrica* in marine facies of the Manacapuru Formation make it the oldest record of South America (Lochkovian). Although *Orbiculoidea* has already been briefly mentioned in the literature in the Manacapuru Formation, this is the first record of *O. baini*, *O. bodenbenderi*, and *O. excentrica* in the Manacapuru Formation, and is also the first occurrence for Northern Brazil.

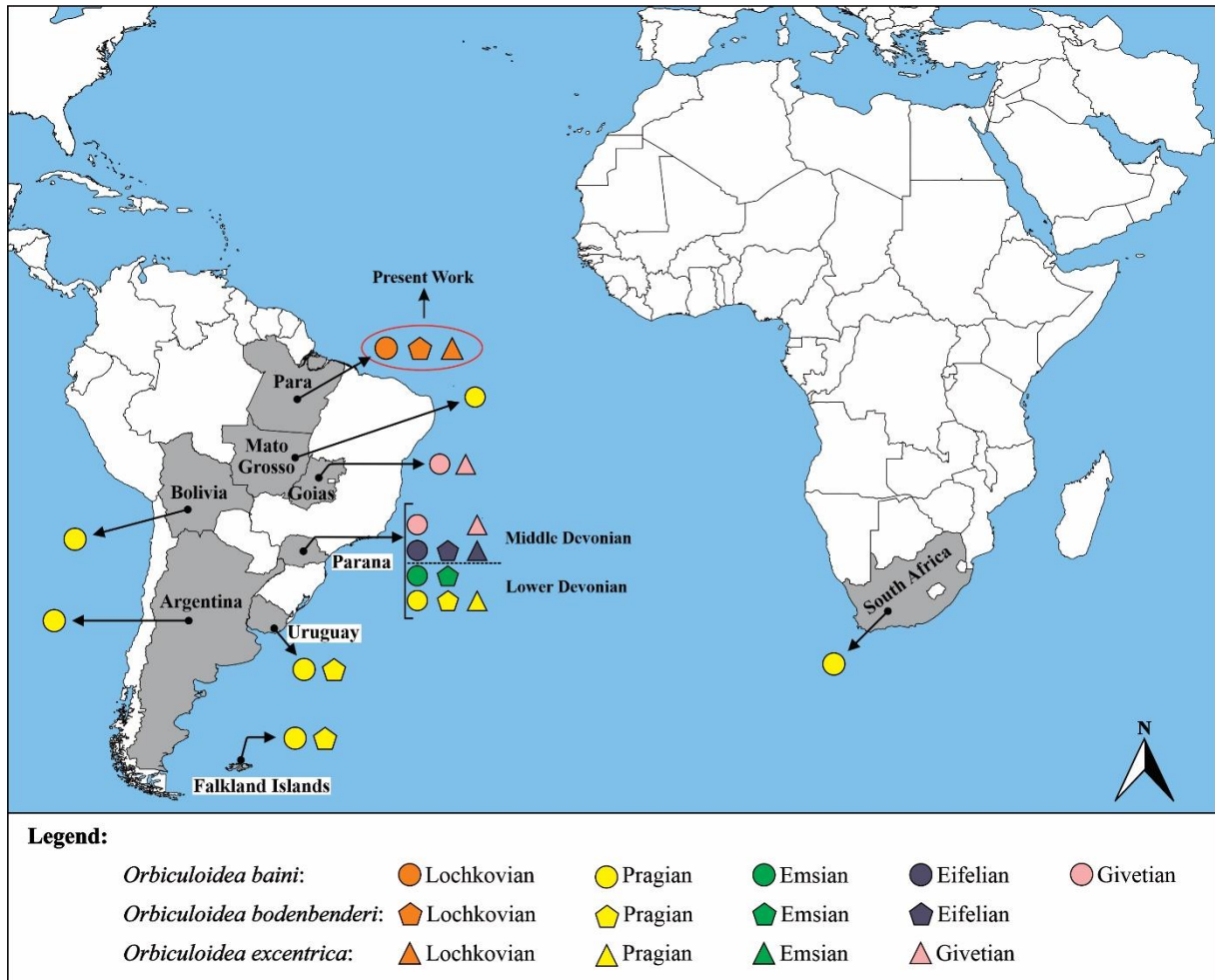


Figure 24- Geographic distribution of *Orbiculoidea baini*, *Orbiculoidea bodenbenderi*, and *Orbiculoidea excentrica*. Source: author.

An important point regarding the *Orbiculoidea* geographical expansion during the Devonian, is Emig's (1997) claim that modern inarticulate brachiopod, have their distribution controlled by environmental factors, and not by the dispersion potential of their larvae. Zhang *et al.* (2018) demonstrated that the distribution of *Orbiculoidea* throughout the Paleozoic would be related to global climate changes and the geographical configuration of continental masses.

Orbiculoidea appeared in the Upper Ordovician, in shallow seas of regions located in low latitudes (South Baltic, West Bank of Gondwana, and in Laurasia) with relatively warm temperatures (Zhang *et al.* 2018). In the Late Ordovician to Early Silurian (Figure 25 A), the Hirnantian Glaciation occurred, which persisted for almost 35 million years (Finnegan *et al.* 2011). Climatic conditions were quite severe in Gondwana, with the persistence of only a few discinoids, such as *Kosoidea australis*, from the Iapó and Vila Maria formations (Parana Basin), recorded by Zabini *et al.* (2019). During the Silurian, post-glacial warming was slow in Gondwana, and the environmental conditions were very unstable (Torsvik & Cocks 2013),

disfavoring *Orbiculoidea* colonization in this region. Much of the *Orbiculoidea* records are limited to low latitudes (part of Laurasia and southern China) (Figure 25 B).

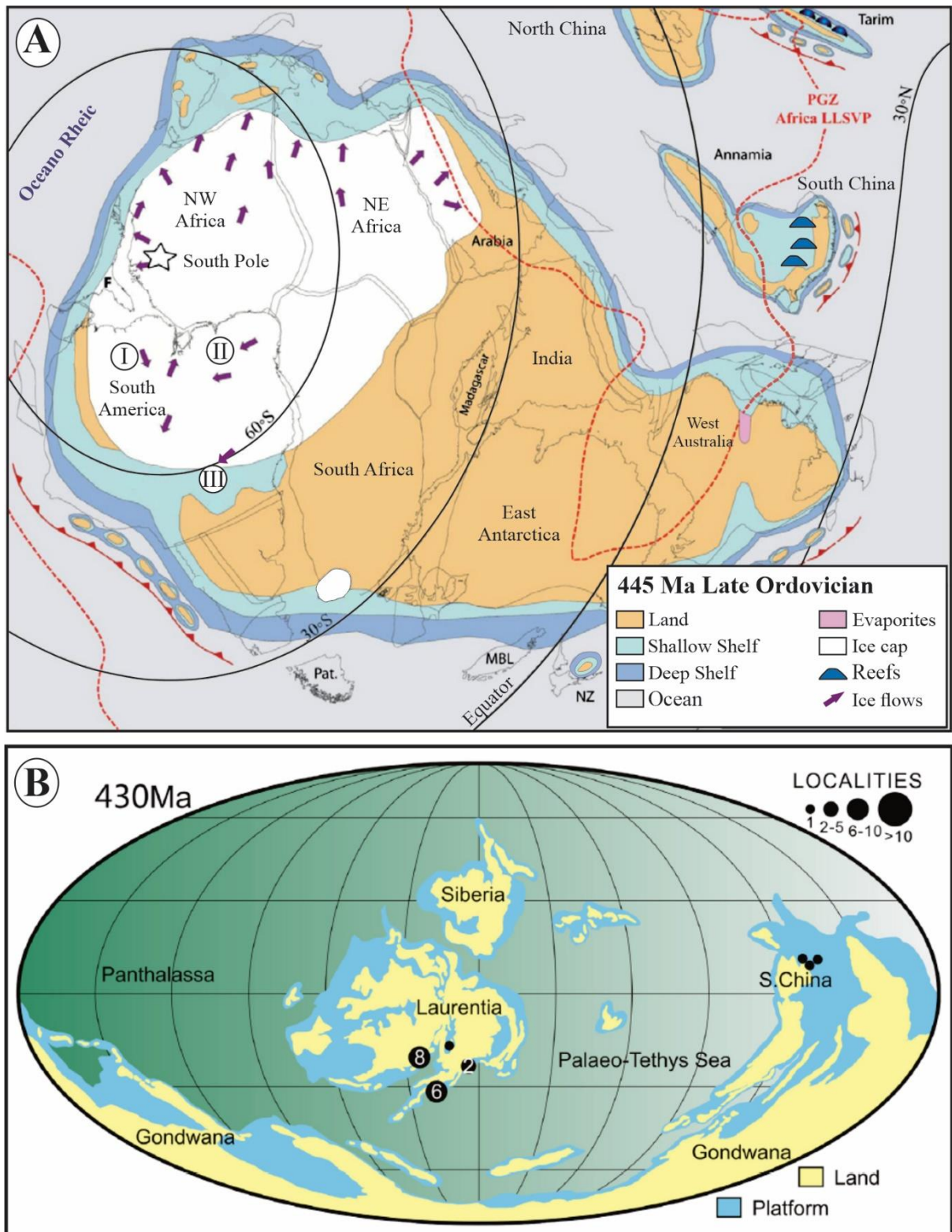


Figure 25- A) Gondwana 445 Ma paleogeographic arrangement. I) Amazonas Basin; II) Parnaiba Basin; III) Parana Basin. B) Distribution of the *Orbiculoidea* genus during the Silurian (430 Ma); black numbers and circles represent the number of occurrences. Source: A) modified from Torsvik & Cocks (2013); B) modified from Zhang *et al.* (2018).

The paleobiogeographic distribution of *Orbiculoidea* expanded significantly to high latitudes during the Lower Devonian (Figure 26 B), especially in Gondwana (Zhang *et al.* 2018). This migration is linked to two factors: the main continental blocks (Laurasia and Gondwana) were close enough to allow the larvae of invertebrates (*Orbiculoidea*) to cross the oceans more easily (Torsvik & Cocks 2013, Zhang *et al.* 2018) (Figure 26 A).

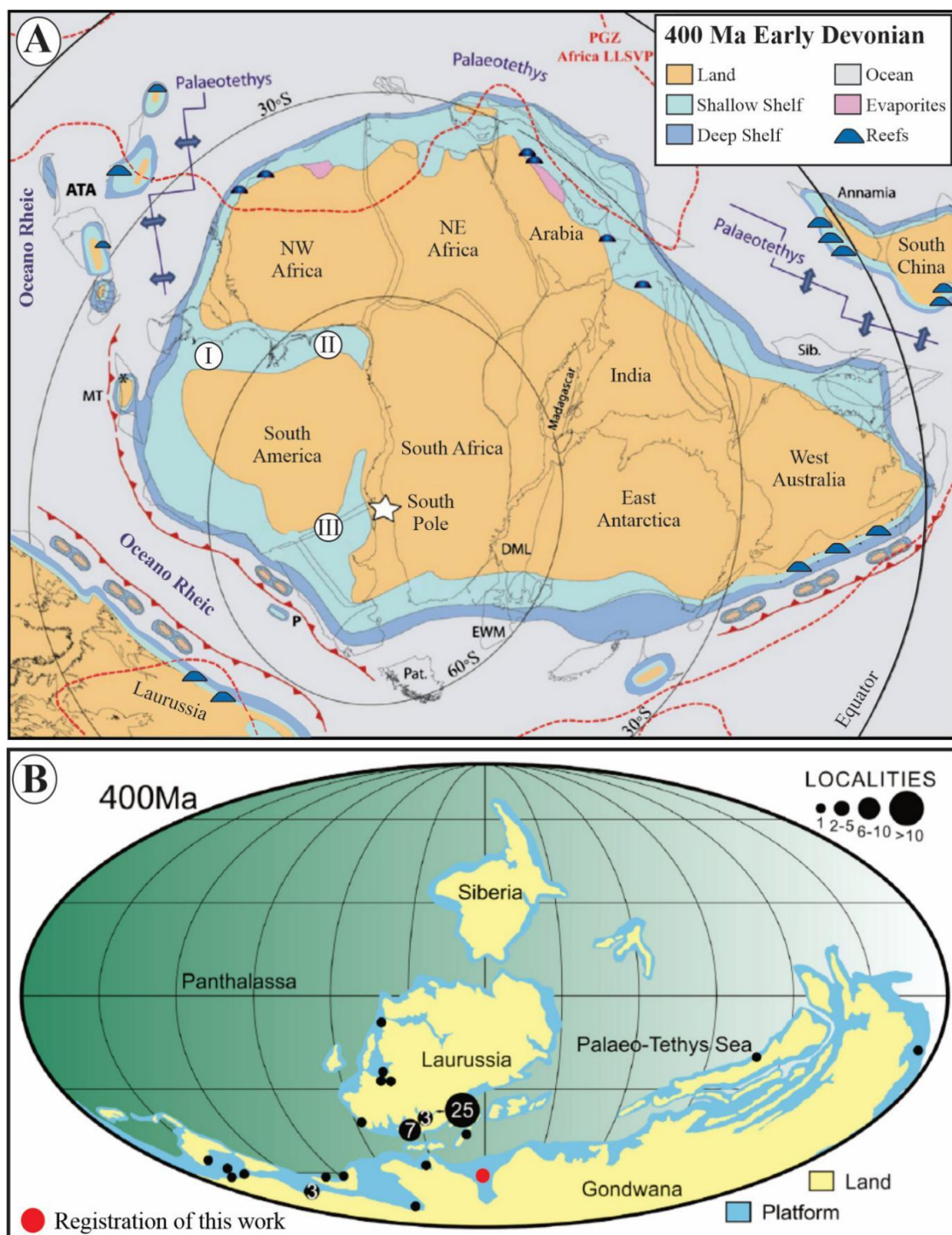


Figure 26- A) Gondwana 400 Ma paleogeographic arrangement. I) Amazonas Basin; II) Parnaiba Basin; III) Parana Basin. B) Distribution of the *Orbiculoidea* genus during the Lower Devonian (400 Ma); black numbers and circles represent the number of occurrences. Source: A) modified from Torsvik & Cocks (2013); B) modified from Zhang *et al.* (2018).

The other factor is that during the transition from the Silurian to the Devonian, occurred the melting of the polar ice caps that covered part of Africa and South America, resulting in marine transgressions that reached a large part of the supercontinent Gondwana, mainly the northwest portion (Carozzi *et al.* 1973, Caputo 1984, Johnson 2006, Torsvik & Cocks 2013). Such conditions were fundamental for the significant paleogeographic distribution of brachiopods in Gondwana during the Devonian.

These transgressions associated with the approximation of the continental masses and to less severe temperatures when compared to the Early Silurian, were probably one of the factors that caused a notable increase in the shallow water benthic faunas in Gondwana (Boucot and Blodgett 2001, Torsvik & Cocks 2013, Zhang *et al.* 2018).

During the Lochkovian (Lower Devonian), the siliciclastic sediments of the upper portion of the Manacapuru Formation (Amazonas Basin) were deposited in a shallow platform environment (Carozzi *et al.* 1973, Cunha *et al.* 2007, Rocha *et al.* 2019). The Amazonas Basin was closer to Laurasia, the environmental conditions were marine, the climate was not as severe as at the beginning of the Silurian, and these conditions probably enabled the migration of *Orbiculoidea* larvae from Laurasia to the Amazonas Basin first, as shown by the records of *O. baini*, *O. bodenbenderi*, and *O. excentrica* in strata of the Manacapuru Formation shown in the present work.

The siliciclastic rocks of the Furnas Formation register the Lower Devonian in the Parana Basin, with a complex depositional environment, that generated a great number of debates (Milani *et al.* 2007). Many authors suggest shallow marine conditions (Petri 1948, Sanford & Lange 1960, Bigarella *et al.* 1966, Lange & Petri 1967, Bigarella 1973). On the other hand, Zalán *et al.* (1987) point to a fluvial origin. While Bergamaschi (1992) and Assine *et al.* (1994) indicate deltaic and marine platform conditions. Nevertheless, what we do know is that there is no occurrence of *Orbiculoidea* recorded in the literature for this interval.

Subsequently, in the Pragian (Ponta Grossa Formation), with the establishment of marine conditions (shallow platform), there are the first occurrences of *Orbiculoidea baini*, *O. bodenbenderi*, *O. excentrica*, *Gigadiscina collis*, and *Rugadiscina stagona* in strata of the Parana Basin (Clarke 1913, Lange 1943, 1954, Comniskey & Bosetti 2017). This diverse fauna was more abundant during the end of Pragian and the beginning of Emsian (Comniskey & Bosetti 2017).

At the end of Emsian, there was a decline in the distribution and abundance of the discinoids of the Devonian of the Parana Basin. Species such as *Orbiculoidea bodenbenderi*, *Gigadiscina collis*, and *Rugadiscina stagona*, in addition to other organisms belonging to the

Malvinokaffric Realm, were no longer found in sedimentary successions (Bosetti *et al.* 2012, Comniskey & Bosetti 2017).

Horodyski *et al.* (2014) detected evidence of the global Kačák Eifelian/Givetian transition event in the Parana Basin. The Kačák event is associated with a transgressive peak which would have resulted in drastic environmental changes, such as changes in temperature and a period of global anoxia, which would have affected primary production (House 1996, 2002).

This biotic crisis resulted in the extinction of a large part of the discinoids in the Devonian. *Orbiculoidea baini* and *O. excentrica* are described with reduced sizes (90% smaller) in the Givetian strata of the São Domingos Formation. This drastic reduction in size of these discinoids is a consequence of the Lilliput Effect (Bosetti *et al.* 2010, Comniskey *et al.* 2016, Comniskey & Bosetti 2017). There are no occurrences of discinoids in the younger units, indicating that the discinoids disappeared in the Givetian (Late Devonian) (Comniskey *et al.* 2016).

5.6 CONCLUSIONS

The taxonomical study of the Brachiopoda (Discinoidea) from Belo Monte, municipality of Vitoria do Xingu, State of Pará, allowed to recognize five species of *Orbiculoidea*: *Orbiculoidea baini*, *O. bodenbenderi*, *O. excentrica*, and two new species described herein *O. xinguensis* sp. nov. and *O. katzeri* sp. nov. These are the first records of the species *O. baini*, *O. bodenbenderi*, and *O. excentrica* in the Manacapuru Formation, and also the first occurrences for Northern Brazil. This Early Devonian discinoids association is the oldest of South America.

The presence of discinoids in the strata of the Manacapuru Formation suggests a shallow marine environment, corroborating the environment proposed earlier for the upper part of that formation. Their occurrences in the transition of sandstones to finer laminated siltstones layers indicate that they were deposited under high to low energy. It corroborates that the discinoids have preference for shallow water. This group has been recorded also in sandstones and siltstones of the São Domingos and Ponta Grossa formations, Parana Basin.

ACKNOWLEDGMENTS

The authors would like to thank the Museu Paraense Emilio Goeldi (MPEG) for the infrastructure provided by the laboratories of the Coordenação de Ciências da Terra e Ecologia. The Federal University of Pará (UFPA) supported this research through the Programa de Pós

Graduação em Geologia e Geoquímica (PPGG), and to Sergio Agustín Martínez Chiappara for the valious contribution to the language review and comments. This work was carried out with the support of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-Brazil (CAPES) – financing code 001.

REFERENCES

- Almeida F. F. M. 1967. Origem da plataforma brasileira. *Boletim da divisão de Geologia e Mineralogia*, Rio de Janeiro, **241**: 36.
- Andrade S. M. & Camarço P. E. N. 1980. Estratigrafia dos sedimentos devonianos do flanco nordeste da Bacia do Paraná. In: 31° Congresso Brasileiro de Geologia, Camboriú, **5**: 2828-2836.
- Assine M. L., Soares P. C., Milani E. J, 1994. Sequências tectono-sedimentares Meso-Paleozoicas da Bacia do Paraná, Sul do Brasil. *Revista Brasileira de Geociências*, **24**:77-89.
- Bergamaschi S. 1992. Análise sedimentológica da Formação Furnas na faixa de afloramentos do flanco norte do arco estrutural de Ponta Grossa, Bacia do Paraná, Brasil. Master's Dissertation, Geology Federal University of Rio de Janeiro, Rio de Janeiro, p. 1-172.
- Bigarella J. J. 1973. Paleocorrentes e deriva continental (comparação entre África e América do Sul). *Boletim Paranaense de Geociências*, **31**:141-224.
- Bigarella J. J., Salamuni R., Marques F. L. P. 1966. Texturas e estruturas da Formação Furnas e sua significação paleogeográfica. *Boletim da Universidade Federal do Paraná*, **18**: 1-114.
- Bosetti E. P., Horodyski R. S., Zabini C., Matsumura W. M. K., Penteado, A.C. 2010. Ocorrência de fenótipos subnormais no topo da Formação Ponta Grossa (Devoniano), Tibagi, estado do Paraná, Brasil: implicações tafonômicas e Paleossinecológicas. *Boletim do Museu Paraense Emílio Goeldi*, **5**(2): 135-149.
- Bosetti E. P., Grahn Y., Horodyski R. S., Mauller P. M. 2012. The first recorded decline of the Malvinokaffric Devonian fauna in the Paraná Basin (southern Brazil) and its cause; taphonomic and fossil evidences. *Journal of South American Earth Sciences*, **37**:228-241.
- Boucot A. J. & Blodgett R. B. 2001. Silurian-Devonian biogeography. In: Brunton C. H. C., Cocks L. R. M., Long S. L. (Eds.), *Brachiopods Past and Present*. Taylor and Francis, London, p.335-344.
- Boucot A. J., Rowell A. J., Racheboeuf P., Pereira E., Melo J. H. G., Siqueira L. P. 2001. Position of the Malvinokaffric Realm's northern boundary (Early Devonian) based on newly discovered brachiopods from the Parecis Basin (Brazil). *Journal of the Czech Geological Society*, **46**: 109-120.
- Caputo M. V. 1984. Stratigraphy, tectonics, paleoclimatology and paleogeography of northern basins of Brazil. Phd Thesis, Universidade da California, p. 1-603.
- Caputo M. V. & Crowell J. C. 1985. Migration of glacial centers across Gondwana during Paleozoic Era. *Geological Society of America Bulletin*, **96**(8): 1020-1036.
- Caputo M. V., Rodrigues R., Vasconcelos D. N. N. 1971. Litoestratigrafia da Bacia do Amazonas. Relatório Técnico Interno. 641-A, Petrobras-Renor, p. 35-46.

- Carbonaro F. A., Comniskey J. C., Corral H. S., Ghilardi R. P. 2018. *Orbiculoidea baini* and *Orbiculoidea excentrica* (Brachiopoda, Discinidae) from the Middle Devonian (Alto Garças Sub-basin, Paraná Basin) of Caiapônia, Goiás (Brazil). *Geologia USP, Série Científica*, **18**(4): 11-20.
- Carbonaro F. A. & Ghilardi R. P. 2016. Fósseis do Devoniano de Goiás, Brasil (Sub bacia Alto Garças, Bacia do Paraná). *Papéis Avulsos de Zoologia*, **56**(11): 135-149.
- Carozzi A. V., Pamplona H. R. P., Castro J. C., Contreiras C. J. A. 1973. Ambientes Depositionais e Evolução Tecto-sedimentar da Seção clástica Paleozoica da Bacia do Médio Amazonas. *Anais do 28º Congresso Brasileiro de Geologia*. Aracaju, 279-314.
- Chuang S. H. 1961. Growth of the postlarval shell in *Lingula unguis* (L.) (Brachiopoda). *Proceedings of the Zoological Society of London*, **137**: 299-310.
- Clarke J. M. 1913. Fósseis devonianos do Paraná. *Monographias do Serviço Geológico e Mineralógico do Brasil, Rio de Janeiro*, **1**: 1-353.
- Clarkson E. N. K. 1992. *Invertebrate Palaeontology and Evolution*. Chapman and Hall, **3**: 153.
- Comniskey J. C. & Bosetti E. P. 2017. Discinoids of the Malvinokaffric Realm: Stratigraphic, Paleogeographical Distribution and Systematic Review. *Terr@Plural*, **11**(2): 175-192.
- Comniskey J. C., Bosetti E. P., Horodyski R. S. 2016. Taphonomic aspects and the Lilliput Effect on Devonian discinoids of the Paraná Basin, Apucarana Sub-basin, Brazil. *Gaea: Journal of Geosciences*, **9**(1): 55-64.
- Comniskey J.C. 2011. Paleontologia dos Discinidae (Brachiopoda: Linguliformea) da sucessão devoniana da Bacia do Paraná, Estado do Paraná, Brasil: Revisão Sistemática, distribuição geográfica e estratigráfica. Ponta Grossa, Paraná. Master's Dissertation, Geology State University of Ponta Grossa, p. 1-179.
- Cunha P. R. C., Gonzaga F. G., Coutinho L. F. C., Feijó F.J. 1994. Bacia do Amazonas. *Boletim de Geociências da PETROBRAS*, **8**: 47-55.
- Cunha P. R. C., Melo J. H. G., Silva O. B. 2007. Bacia do Amazonas. *Boletim de Geociências da PETROBRAS*, **15**: 227-251.
- d'Orbigny A. 1847. Considérations zoologiques et géologiques sur les Brachiopodes ou Palliobranches. *Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences*, **25**(7): 266-269.
- Davidson T. 1848. Mémoire sur les brachiopods du Système silurien supérieur de l'Angleterre. *Bulletin de la Société géologique de France, série* **2**(5): 370-374.
- Davila J. & Rodriguez E. 1967. The Devonian System in Bolivia and the problem of its base. *International symposium Devonian System*, **2**: 921-935.
- Emig C. C. 1997. Ecology of inarticulated brachiopods. In: Kaesler R. L., (ed.) *Treatise on invertebrate paleontology*. Part H. Brachiopoda 1 (revised). Geological Society of America and University of Kansas Press, p. 473-495.
- Figueiras A. 1991. Fauna eodevonica del Uruguay. *Revista Técnica da YPF*, **12**(1): 57-64.

- Finnegan S., Bergmann K., Eiler J. M., Jones D. S., Fike D. A., Eisenman I., Hughes N. C., Tripathi A. K., Fisher W. W. 2011. The magnitude and duration of late Ordovician-early Silurian glaciation. *Science*, **331**(6019): 903-906.
- Fonseca V. M. M. & Ponciano L. C. M. O. 2011. Braquiópodes do Devoniano Médio das bacias do Amazonas e Parnaíba. In: Carvalho I. S. (Org.). *Paleontologia: Cenários de Vida*. Rio de Janeiro: Editora Interciência, **1**(4): 169-190.
- Gorjansky V. IU. & Popov, L. E. 1985. Morphology, systematic position and origin of the inarticulate brachiopods with calcareous shells. *Paleontologicheskii Zhurnal* **3**: 3–14.
- Grahn Y. 2005. Silurian and Lower Devonian chitinozoan taxonomy and biostratigraphy of the Trombetas Group, Amazonas Basin, northern Brazil. *Bulletin of Geosciences, Prague*, **80**(4): 245-276.
- Grahn Y. & Caputo M.V. 1992. Early Silurian glaciations in Brazil. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **99**: 9-15.
- Grahn Y. & Melo J. H. G. 1990. Bioestratigrafia dos quitinozoários do Grupo Trombetas nas faixas marginais da Bacia do Amazonas. Rio de Janeiro: PETROBRAS. Report produced for the Eletrobras Eletronort, p. 43.
- Grahn Y. & Paris F. 1992. Age and correlation of the Trombetas Group, Amazonas Basin, Brazil. *Revue de Micropaléontologie*, **35**:197-209.
- Gray J. 1840. Synopsis of the contents of the British Museum. London: British Museum, 42° International Symposium Devonian System, **2**: 921-935.
- Holmer L. E. & Popov L. E. 2000. Lingulata. In: Williams A., Brunton C. H. C., Carlson S. J. *Treatise on Invertebrate Paleontology. Part H, Brachiopoda, Revised*. Geological Society of America and University of Kansas Press, Boulder, **2**: 30–146.
- Horodyski R. S., Holz M., Grahn C. Y., Bosetti E. P. 2014. Remarks on the sequence stratigraphy and taphonomy of the relictual Malvinokaffric fauna during the Kačák event in the Paraná Basin, Brazil. *International Journal of Earth Sciences*, **103**: 367-380.
- House M. R. 1996. The middle Devonian Kačák event. Read at the Annual Conference of the Ussher Society, p. 79-84.
- House M. R. 2002. Strength, timing and cause of mid-Paleozoic extinctions. *Paleogeography, Palaeoclimatology and Paleoecology*, **181**:5-25.
- Janvier P. & Melo J. H. G. 1988. Acanthodian fish remains from the Upper Silurian or Lower Devonian of the Amazonas basin, Brazil. *Palaeontology*, **31**(3): 771-777.
- Johnson M. E. 2006. Relationship of Silurian sea-level fluctuations to oceanic episodes and events. *GFF*, **128**(2): 115-121.
- Klemme H. D. 1980. Petroleum basins – classification and characteristics. *Journal of Petroleum Geology, Beaconsfield*, **3**(2): 187-207.
- Kozłowski R. 1913. Fósiles Dévoniens de l' état de Paraná (Brésil). *Annales de Paleontologie Paris*, **8**(3): 1-19.
- Lange F. W. 1943. Novos fósseis devonianos do Paraná. *Arquivos Museu Paranaense*, **3**: 223-225.

- Lange F. W. 1954. Paleontologia do Paraná: volume comemorativo do 1º Centenário do Estado do Paraná. Curitiba: Comissão de Comemorações do Centenário do Paraná, p. 1-210.
- Lange F. W. 1967. Subdivisão bioestratigráfica e revisão da coluna siluro-devoniana da bacia do baixo Amazonas. In: In: Simpósio sobre a biota amazônica. Belém. Atas, **1**: 215-326.
- Lange F. W. & Petri S. 1967. The Devonian of the Paraná Basin. In: Bigarella J. J. (ed.) Problems in Brazilian Devonian Geology. Boletim Paranaense de Geociências, **21**(22): 5-55.
- Ludwig G. 1964. Divisão estratigráfico-faciológica do Paleozoico da Bacia Amazônica. PETROBRAS, Ciência Técnica Petróleo, Seção: Exploração de petróleo, **1**: 1-72.
- Melo J. H. G. 1985. A Província Malvinocáfrica no Devoniano do Brasil: estado atual dos conhecimentos. Master's Dissertation, Geology Federal University of Rio de Janeiro, p. 1-890.
- Melo J. H. G. 1988. The Malvinokaffric realm in the Devonian of Brazil. In: Mcmillan N. J., Embry A. F., Glass O. J. (Eds.) Devonian of the world. Canadian Society of Petroleum Geologists, Memoir, Calgary, **14**(1): 667-703.
- Méndez-Alzola R. & Sprechmann P. 1971. Algunas orbiculoideas devónicas de la Precordillera de San Juan, Rep. Argentina. Revista de la Asociacion Geologica Argentina, **26**(4): 517-525.
- Mergl M. 2001. Lingulate brachiopods of the Silurian and Devonian of the Barrandian. Acta Musei nationalis Pragae, Series B – historia naturalis, **57**(1-2): 1-49.
- Milani E. J., França A. B., Medeiros R. Á. 2007. Rochas geradoras e rochas reservatório da Bacia do Paraná, faixa oriental de afloramentos, Estado do Paraná. Boletim de Geociências da Petrobrás, **15**: 135-162.
- Northfleet A. A., Medeiros R. A., Mullmann H. 1969. Reavaliação dos dados geológicos da Bacia do Paraná. Boletim Técnico da Petrobrás, **12**(3): 291-346.
- Petri S. 1948. Contribuição do estudo do Devoniano paranaense. Boletim da Divisão de Geologia e Mineralogia, DNPM, **129**:1-125.
- Ponciano L. C. M. O., Fonseca V. M. M., Costa M. D. M. 2012. Tafocenoses da Formação Pimenteira, Devoniano da Bacia do Parnaíba, Piauí: mapeamento, inventário e relevância patrimonial. Anuário do Instituto de Geociências, **35**(1): 5-27.
- Popov L. E., Holmer L. E., Bassett M. G., Ghobadi P. M., Percival I. G. 2013. Biogeography of Ordovician linguliform and craniiform brachiopods. In Harper D. A. T., Servais T. (Eds). Early Palaeozoic biogeography and palaeogeography. Geological Society, London, Memoirs, **38**: 117–126.
- Quadros L. P. 1985. Distribuição bioestratigráfica dos Chitinozoa e Acritarchae na Bacia do Amazonas. Ph.D. Thesis, Universidade Federal do Rio de Janeiro.
- Reed F. R. C. 1903. Brachiopoda from the Bokkeveld beds. South Africam Mussem Annals, **4**: 165-197.
- Reed F. R. C. 1925. Revision of the fauna of the Bokkeveld Beds. South African Museum Annals, **22**: 27-225.
- Rocha P. F., Silveira R. R., Barbosa R. C. M. 2019. Age and palaeoenvironments of the Manacapuru Formation, Presidente Figueiredo (AM) region, Lochkovian of the Amazonas Basin. Brazilian Journal of Geology, **49**(4): 1-12.

- Sanford R. M., Lange F. W. 1960. Basin study approach to oil evaluation of Paranamiogeosyncline, south Brazil. *American Association of Petroleum Geologists Bulletin*, **44**:1316-1370.
- Schneider R. L., Muhlmann H., Tommasi E., Medeiros A., Daemon R. F., Nogueira A. A. 1974. Revisão estratigráfica da Bacia do Paraná. In: 28 °Congresso Brasileiro de Geologia, Porto Alegre, Anais, **1**: 41-65.
- Sharpe D. 1856. Description of Palaeozoic mollusca from South Africa. *Trans. Geol. Soc. London*, **2**(7): 206-215.
- Souza V. S. & Nogueira A. C. R. 2009. Manaus-Presidente Figueiredo (AM), borda norte da Bacia do Amazonas: um guia para excursão de campo. *Revista Brasileira de Geociências*, **39**(1): 16-29.
- Stemans P., Rubinstein C., Melo J. H. G. 2008. Siluro-Devonian miospore biostratigraphy of the Urubu River area, western Amazonas Basin, northern Brazil. *Geobios*, **41**(2): 263-282.
- Sudkamp W. H. 1997. Discovered of soft parts of a fossil brachiopod in the “Hunrsucksciefer” (Lower Devonian, Germany). *Palaontologische Zeitschrift*, **71**: 91-95. 1997.
- Tomassi H. Z., Almeida C. M., Ferreira B. C., Brito M. B., Barberi M., Rodrigues G. C., Teixeira S. P., Capuzzo J. P., Gama-Júnior J. M., Santos M. G. K. G. 2015a. Preliminary results of paleontological salvage at Belo Monte Powerplant construction. *Brazilian Journal of Biology*, **75**(3): 277-289.
- Tomassi H. Z., Ferreira B. C., Almeida C. M., Barberi M., Brito M. B., Ramos L. S. 2015b. Relatório Técnico Final do Programa de Salvamento do Patrimônio Paleontológico da Usina Hidrelétrica de Belo Monte. *TERRAGRAPH Paleontologia*, Belém, **1**: 1-50.
- Torsvik T. H., Cocks L. R. M. 2013. Gondwana from top to base in space and time. *Gondwana Research*, **24**: 999-1030.
- Waagen W. 1885. Productus Limestone Fossils. *Palaeontology Indica*, **13**(1): 729-770.
- Wanderley Fiho J. R., Melo J. H. G., Fonseca V. M. M., Machado D. M. C. 2005. Bacias sedimentares brasileiras: Bacia do Amazonas. *Phoenix*, Aracajú, **7**(82): 1-6.
- Winrow P. & Sutton M. D. 2014. Lingulate brachiopods and the Early Palaeozoic history of the Iapetus Ocean. *Lethaia*, **47**: 456-468.
- Zabini C., Comiskey J.C., Bosetti E.P. 2013. John Mason Clarke e os lingulídeos e discinídeos dos estratos devonianos da Bacia do Paraná, estado do Paraná, Brasil: estado da arte. *Revista Terr@ Plural*, **7**: 43-58.
- Zabini C., Furtado-Carvalho A. B., Carmo D., Assine M. L. 2019. A new discinoid *Kosoidea australis* sp. nov. from the Iapó and Vila Maria Formations, NE Paraná Basin, Brazil. *Historical Biology*, p. 1-9.
- Zalán P. V., Wolff S., Conceição J. C. J., Vieira I. S., Astolfi M. A. M., Appi V.T., Zanotto O. A. 1987. A divisão tripartite do Siluriano da Bacia do Paraná. *Revista Brasileira de Geociências*, **17**: 242-252.
- Zhang Y., Lee S., Wu H. T., He W. H. 2018. Palaeobiogeographical distribution of *Orbiculoidea* (Brachiopoda, Discinoidea) responding to global climatic and geographical changes during the Palaeozoic. *Palaeontology*, **61**(2): 221-234.

CAPÍTULO 6 SCHELLWIENELLA AMAZONENSIS NEW SPECIES (ORTHOTETIDA, BRACHIOPODA): THE FIRST RECORD OF THE GENUS FROM THE DEVONIAN OF THE AMAZONAS BASIN (MANACAPURU FORMATION – LOCHKOVIAN), NORTH BRAZIL

Luiz Felipe Aquino Corrêa ^a, Maria Inês Feijó Ramos ^b, and João Marcelo Pais de Rezende ^c

^a *Geosciences Institute, Federal University of Pará, Rua Augusto Corrêa, 1 - Guamá, 66075-110, Belém-PA, Brazil;*

^b *Museu Paraense Emílio Goeldi, Coordination of Earth sciences, Avenida Perimetral, 1901 - Terra Firme, 66077-830, Belém-PA, Brazil.*

^c *Laboratório de Sistemática e Biogeografia, Universidade do Estado do Rio de Janeiro – LABSISBIO-UERJ*

Artigo submetido ao periódico **Journal of South American Earth Sciences**

← Submissions Being Processed for Author

Page: 1 of 1 (1 total submissions) Results per page 10

Action	Manuscript Number	Title	Initial Date Submitted	Status Date	Current Status
View Submission Send E-mail	SAMES-D-24-00528	SCHELLWIENELLA AMAZONENSIS NEW SPECIES (ORTHOTETIDA, BRACHIOPODA): THE FIRST RECORD OF THE GENUS FROM THE DEVONIAN OF THE AMAZONAS BASIN (MANACAPURU FORMATION – LOCHKOVIAN), NORTH BRAZIL	Sep 05, 2024	Sep 05, 2024	Submitted to Journal

Page: 1 of 1 (1 total submissions) Results per page 10

ABSTRACT

The Devonian was a critical period in brachiopod evolution, during which the phylum reached its maximum diversity in the Emsian and experienced a significant decline during the Frasnian–Famennian, second only to the mass extinction of the Late Permian. The brachiopod fauna of the Manacapuru Formation (Lochkovian) was unknown until 2011, when a significant number of Rhynchonelliformea and Linguliformea samples were recovered during paleontological salvage at the Belo Monte hydroelectric plant in Vitória do Xingu, Pará, Brazil. This study aims to identify the Orthotetida from this salvage. The taxonomic study of the brachiopods from the Manacapuru Formation (Lochkovian) led to the recognition of a new species, *Schellwienella amazonensis* n. sp., Family Pulsiidae Cooper and Grante, 1974. *Schellwienella amazonensis* n. sp. and *Schellwienella marcidula* Amsden, 1958 originally described to the Bois d’Arc

Formation (Lochkovian), USA, being the oldest records of the genus. During the Devonian, *Schellwienella* was present throughout all stages, primarily in the Gondwana siliciclastic marine environments, transitioning between temperate and polar latitudes. In the Carboniferous, its range was shorter, confined to the Tournaisian–Viséan interval, with a preference for warm water environments and carbonate platforms, typical of low latitudes.

Keyword: Brachiopod; Northwest Gondwana; Manacapuru Formation; Paleozoic; *Schellwienella*.

6.1 INTRODUCTION

Brachiopods are marine macroinvertebrates formed by two asymmetric valves of organophosphate or organocarbonate composition (Williams *et al.* 2007). During the Devonian, there was a significant increase in genera diversity, mainly of the Sub-Phylum Rhynchonelliformea, probably caused by favorable environmental conditions, such as the expansion of shallow seas in several regions of northwestern Gondwana (Williams *et al.* 2007, Torsvik & Cocks 2013, Harper *et al.* 2017).

Climate, tectonic, and evolutionary dynamics marked the Devonian period (Dowding *et al.* 2021). The distribution of marine invertebrates such as brachiopods, corals, trilobites, and gastropods suggest global patterns of bioregionalizations mainly for the Early – Middle Devonian (Boucot *et al.* 1969, Penn-Clarke & Harper 2020). During this period, the Amazonas Basin was characterized by a mixed fauna, presenting elements from Malvinohosan and the Eastern Americas realms (Boucot *et al.* 2001, Penn-Clarke & Harper 2020).

With the advancement of taxonomic identifications, paleobiogeographical studies of invertebrates have undergone refinement. In the Amazonas Basin, studies of devonian brachiopods began in the late 19th century, with identifications based on material collected during the "Morgan Expeditions (1870–1871)" and the "Imperial Geological Commission of Brazil (1876)". These expeditions primarily focused on the Maecuru (early Eifelian) and Ererê formations (late Eifelian). Derby (1877), Rathbun (1878), Clarke (1899), and Katzer (1897) were the first to identify the Devonian brachiopods of the Amazonas Basin, later revised by Carvalho (1975), Melo (1985), Fonseca (2004) and Fonseca and Ponciano (2011), always focusing on specimens from the Maecuru (early Eifelian), Ererê (late Eifelian) and Barreirinha (early Frasnian) formations.

More specifically, regarding the Manacapuru Formation (Lochkovian), there is only a register of *Lingula* sp. by Grahn & Melo (1990). During the construction of the Belo Monte Hydroelectric Powerplant (2011-2015) in the municipality of Vitória do Xingu, state of Pará,

around 3,715 samples of paleozoic fossils were recovered, including plant remains, ichnofossils, graptolites, mollusks, arthropods, agnatha, and palynomorphs; Tomassi *et al.* (2015a) highlighted a significant number of Rhynchonelliformea and Linguliformea brachiopods found in the Manacapuru Formation. Meanwhile, Corrêa & Ramos (2021) were the first to conduct taxonomic research on Linguliformea brachiopods from among the recovered specimens, identifying five species of *Orbiculoidea*. However, the rhynchonelliformes has not been studied.

The Rhynchonelliformea has record in almost all Devonian units of the Amazonas Basin, except for the Manacapuru, Jatapu, and Curiri formations (Corrêa & Ramos, 2023). Identifying the brachiopod fauna of the Manacapuru Formation is fundamental to understanding the evolutionary aspects of this group throughout the Devonian and to helping analyze the paleobiogeographic distribution of these organisms. This research aims to conduct a taxonomic identification of this subphylum and to discuss the stratigraphic and geographic distribution of the identified genus.

6.2 GEOLOGICAL SETTING

The intracratonic Paleozoic Amazonas Basin is located in the northern region of Brazil (Figure 27 A) and covers an area of approximately 500,000 km², distributed among the states of Amapá, Amazonas, and Pará (Klemme 1980, Cunha *et al.* 1994). It is separated from the Solimões and Marajó basins by the Purus and Gurupá arches, north limited by the Guiana Shield and south by the Brazilian Shield (Cunha *et al.* 2007). The sedimentary infill consists of two first-order mega-sequences: Paleozoic and Meso-Cenozoic (Matsuda *et al.* 2010). The Paleozoic mega-sequence includes four second-order sequences: Ordovician-Devonian, Devonian-Tournasian, and Pennsylvanian-Permian Sequences (Cunha *et al.* 2007). The Ordovician-Devonian sequence comprises rocks from the Trombetas Group, which registers the early depositional phase in the intracontinental syncline of the Amazonas Basin, characterized by transgressive-regressive pulses.

The Trombetas Group comprises the the Autás-Mirim, Nhamundá, Pitinga, Manacapuru, and Jatapu formations (Figure 27 B). The sediments of the group originated from the alternation between glacial and marine environments, located onlap over the Purus Arch in the westernmost region of the basin. In the eastern portion, sedimentation exceeded the Gurupá Arch (non-existent in this period), favoring the connection with northwestern Africa basins (Cunha *et al.* 2007).

The Manacapuru Formation registers the Siluro-Devonian transition in the Amazonas Basin. It is characterized by fine to medium-grained sandstone, neritic and littoral pelites, shales, and laminated siltstone, deposited in a deltaic and shallow marine environment during the Pridoli–Lochkovian interval (Carozzi *et al.* 1973, Caputo 1984, Cunha *et al.* 1994, Grahn 2005, Cunha *et al.* 2007, Souza & Nogueira 2009). The fossiliferous content includes brachiopods, cnidarians, eurypterid fragments, ichnofossils, palynomorphs, and fish (Quadros 1985, Janvier and Melo 1988, Grahn & Melo 1990, Grahn 2005, Wanderley Filho *et al.* 2005, Steemans *et al.* 2008, Tomassi *et al.* 2015a, Rocha *et al.* 2019, Corrêa & Ramos 2021, Corrêa & Ramos 2023).

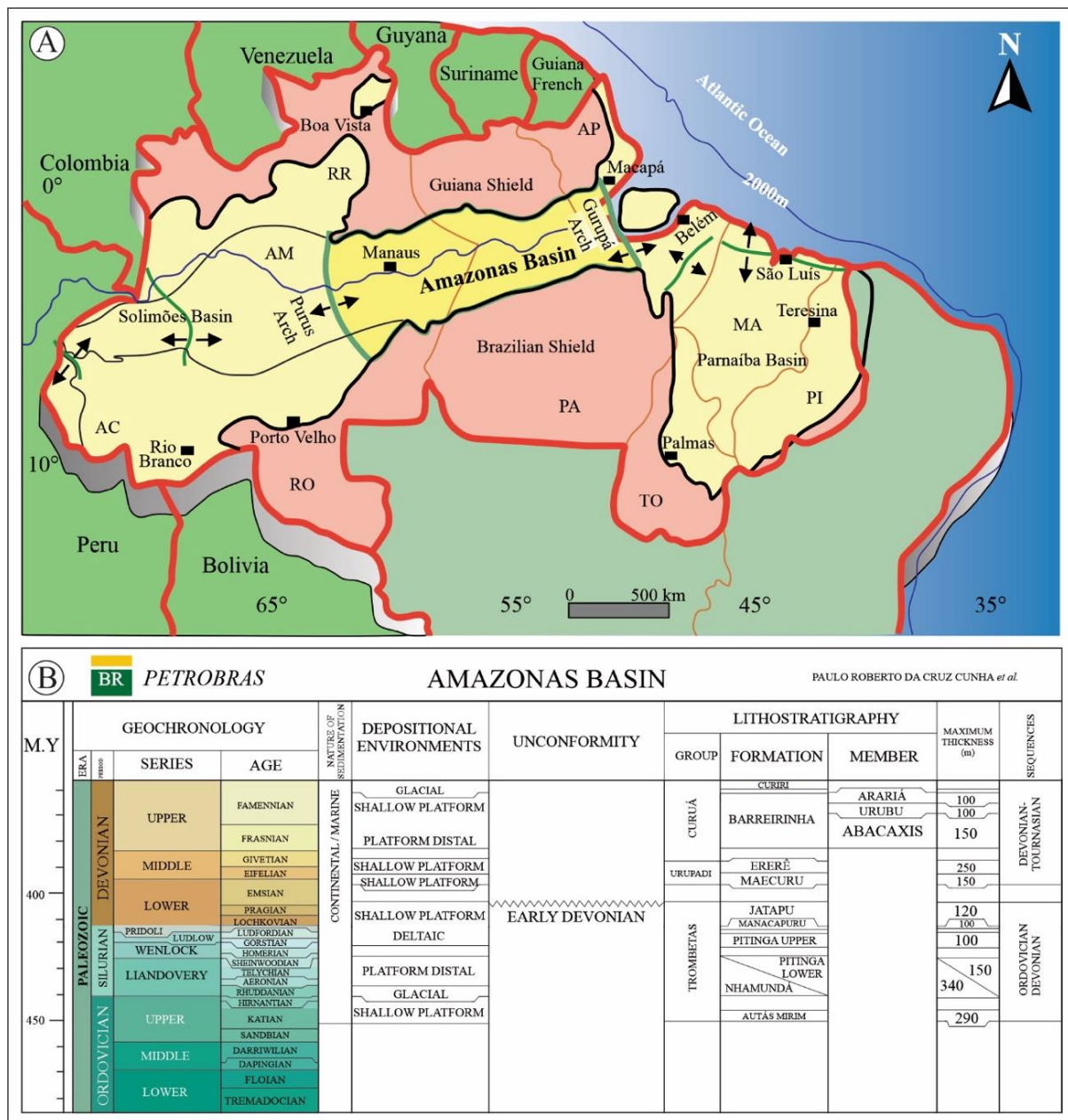


Figure 27- Location of the Amazonas Basin; b) Cronostratigraphic chart of the Amazonas Basin, highlighting the Trombetas Group. Source: a) Cunha (2000); b) Cunha *et al.* (2007).

6.3 MATERIAL AND METHODS

The material investigated is housed at the Coordenação de Ciências da Terra e Ecologia, Museu Paraense Emílio Goeldi under the catalog numbers MPEG-3761-I to MPEG-3878-I, MPEG-3886, MPEG-4156-I, MPEG-4157-Ia, and MPEG-4157-Ib. The Terragraph Paleontologia team collected the material during the paleontological rescue work at the Belo Monte Hydroelectric Powerplant in Vitoria do Xingu, state of Pará (Figure 28), between July 2011 and October 2015. Collection details are described in Tomassi *et al.* (2015a, b).

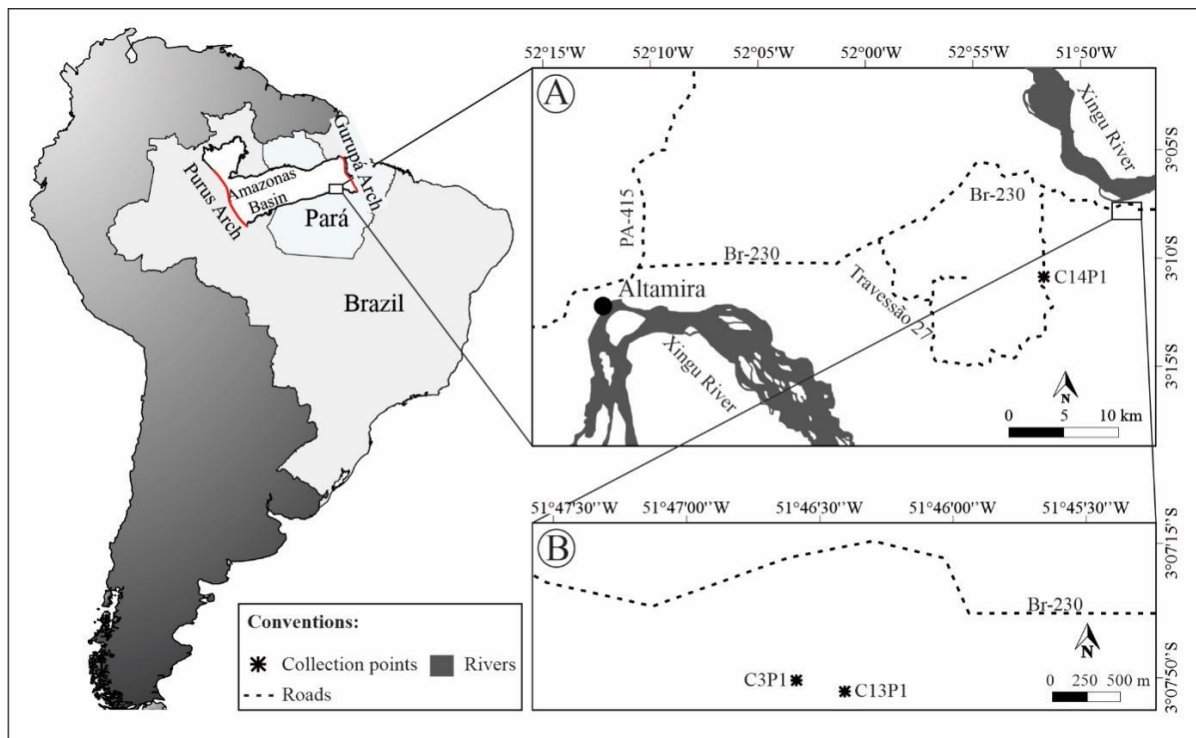


Figure 28- The study area location.

The 178 valves analyzed came from three sections: C3P1, C13P1, and C14P1. From these sections, a stratigraphic profile for the study area was elaborated (Figure 29), all inserted in the upper part of the Manacapuru Formation (Tomassi *et al.* 2015a, Corrêa & Ramos 2021). Most of the studied specimens were collected at the base of the laminated siltstone layer in the C3P1-1 and C3P1-4 sections with sporadic occurrences in the massive sandstone layer from C14P1-1. In addition, four samples (MPEG-0018, MPEG-0026, MPEG-0029, and MPEG-0053) of orthotetids from the Maecuru Formation were also examined, collected by João Coelho in 1895, along with three specimens (MPEG-0159, MPEG-0214, and MPEG-0830) from the Ererê Formation, collected by Frederick Katzer in 1897, all housed in the Museu Goeldi Paleontological collection.

The studied material from Belo Monte is preserved as internal or external molds, counter molds, and composite molds, all disarticulated. Latex casts were made to proper evaluate the internal features of some specimens. All samples were examined under a stereoscopic microscope, and measurements were taken using a caliper. Photographs were captured using a camera attached to the Stereomicroscope LEICA S8 APO. Systematic classification and morphological terminology mainly follow terms applied by Williams & Brunton in Williams *et al.* (2000), Stigall Rode (2005), Basset & Bryant (2006), and Rezende & Isaacson (2021).

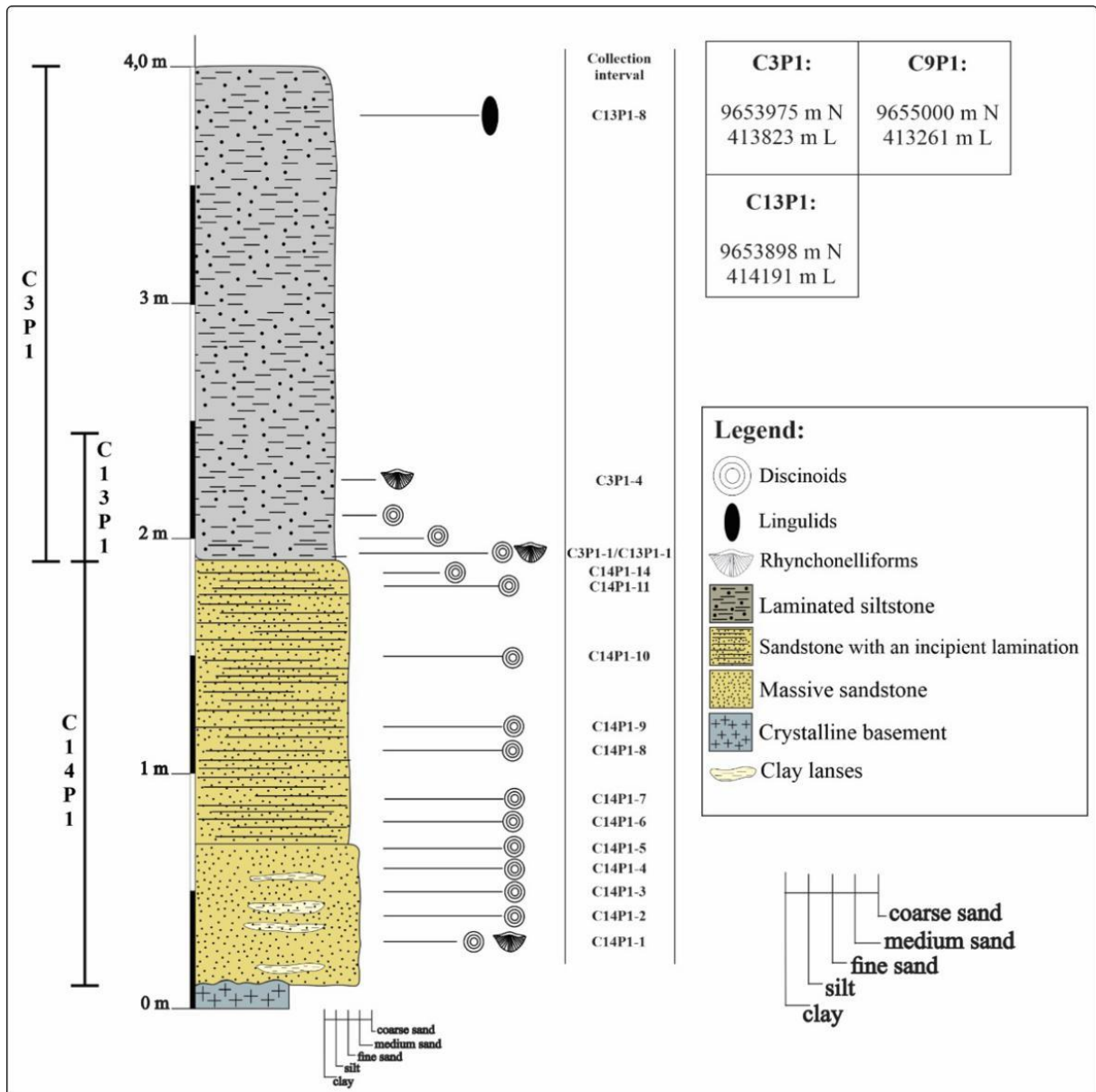


Figure 29- Composed stratigraphic section. Source: Corrêa & Ramos (2021).

6.4 RESULTS

6.4.1 Systematic paleontology

Class Strophomenata Williams *et al.* 1996

Order Orthotetida Waagen, 1884

Suborder Orthotetidina Waagen, 1884

Superfamily Orthotetoidea Waagen, 1884

Family Pulsiidae Cooper and Grant, 1974

Genus *Schellwienella* Thomas, 1910

Type species. — *Spirifera crenistria* Phillips, 1836. Lower Carboniferous (Pendleside Limestone Group, Viséan) of Bowland, Yorkshire, England.

Schellwienella amazonensis new species
(Figures 31 - 35).

Etymology: Dedicated to the geographic (Amazon) and geological (Amazonas Basin) region from which the species was collected.

Types: Holotype: MPEG-3762-Ic; Paratypes: MPEG-3780-Ia, MPEG-3769-Ib, MPEG-3793-Ic, and MPEG-3873-Ib.

Type horizon: Manacapuru Formation (upper unit).

Type locality: Laminated siltstone in section C13P1, Manacapuru Formation (upper sequence), Amazonas Basin.

Material: Ventral valves 108 (external 45 and 63 internal); dorsal valves 70 (51 external and 19 internal). More details **in supplementary material 1** (APÊNDICE - A).

Dimensions: Holotype: MPEG-3762-Ic (w: 9.6 mm; l: 7.6 mm); paratypes: MPEG-3780-Ia (fragmented), MPEG-3769-Ib (w: 7.5 mm; l: 5.2 mm), MPEG-3793-Ic (w: 9.7 mm; l: 7.1 mm), and MPEG-3873-Ib (w: 14.8 mm; l: 10.5 mm). Measurements of ventral and dorsal valves are represented in figure 30. Complete measurement data available **in supplementary material 1** (APÊNDICE - A).

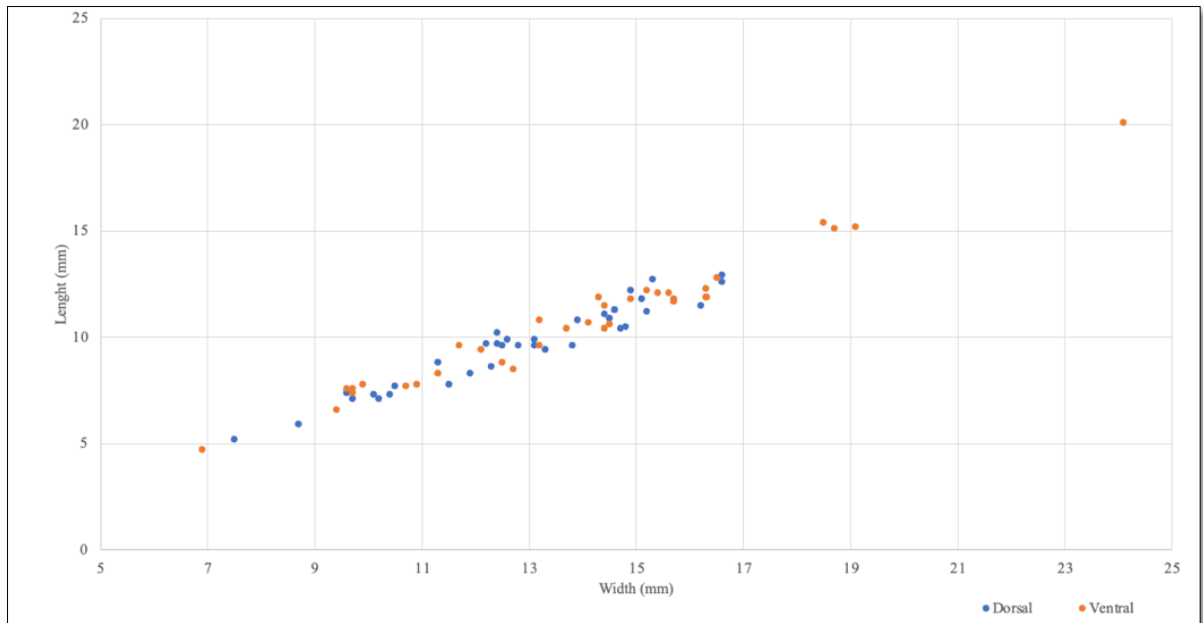


Figure 30- Scatter diagram plotting length to width of *Schellwienella amazonensis* n. sp. from Amazonas Basin, Brazil.

Diagnosis: Dorsibiconvex shell, short dental plate anteriorly divergent, ventral muscle field triangular separated by a median septum of approximately $\frac{1}{2}$ the length of the valve. Parvicostellate ornamentation, with growth lines irregularly spaced and pseudopunctuation in an apparently random pattern.

Occurrence: Sections C3P1, C13P1, and C14P1, located at Sitio Belo Monte, municipality of Vitoria do Xingu, State of Para, Brazil. Manacapuru Formation (Lochkovian), Amazonas Basin.

Description: Shell with subcircular to circular outline. Small to medium size, width (w) varying from 6.9 mm to 24.1 mm and length (l) from 4.7 mm to 20.1 mm. Dorsibiconvex shell. Hinge line straight to weakly triangulate. Shell surface parvicostellate, with costae originating in the apex and costellae by intercalation, with reduced interspace. Growth lines appear irregularly spaced, more frequent as it approaches the anterior rectimarginate commissure. The sectioning by the growth lines causes in some specimens, an ornamentation pattern by multiplication (Figure 35 E). An average of 15 costellae per 5 mm². Proportion of length to width about as 0.68 to 0.83. The ventral valve (Figure 31 A-O) is weakly convex near the umbo, flattening laterally and anteriorly to become flat, while the median portion of the valve presents a groove. Umbo low, ventral beak projected only minimally beyond the hinge line. The dorsal valve (Figure 32 A-O) is moderately convex, higher than the ventral valve. Maximum height located

at the umbo. Dorsal beak high, projected posteriorly beyond the hinge line. Pseudopunctate shell (Figure 35 C-D).

Ventral interior (Figure 33 A-O). Triangular delthyrium closed by a pseudodelthydium (convex in shape), large, triangular-elongated hinge teeth large, supported by short dental plates (24–34 percent of the valve length [n=22]), well-marked, and anteriorly divergent (Figure 35 A -B), varying between 56.49° to 78.95° [n=41], with the lowest value attributed to juvenile specimens (Figure 33 A). The latter, in juvenile specimens, can be smaller, becoming wider in ontogeny. The muscle field is triangular, formed by a subcircular to circular, anteriorly striated diductor scars (Figure 35 A - B), that completely surrounds the lanceolate adductor scars. The field is divided by a median septum (Figure 35 A -B), which reach 40 to 51 percent of the valve's length [n=17]. Adductor scars are situated between the cardinal margin and mid-length of the dental plates; diductor scars larger, extend anteriorly beyond the limit of the dental plate extensions. Pseudopunctuation with no distribution pattern.

Dorsal interior (Figure 34 A-L). Bilobed cardinal process, with elongated lobes (Figure 34 A-B), exposed by posteriorly open notothyrium, covered by a convex chilidium. Dental sockets are short, deep, and divergent; with angles varying between 68.66° and 75.17° [n=11], supported by short and straight socked plates. Triangular umbo, well marked. Median septum present, splitting lanceolate adductor scars, not as marked as the one in ventral valves, and extending proximately one-third the length of the valve.



Figure 31- *Schellwienella amazonensis* n. sp., external ventral valves. A) MPEG-3838-I mold; B) MPEG-3827-Ia mold; C) MPEG-3780-Ia mold; D) MPEG-3818-I mold; E) MPEG-3816-Ia countermold; F) MPEG-3802-Ic mold; G) MPEG-3762-Id mold; H) MPEG-3830-Ia mold; I) MPEG-4157-Ib mold; J) MPEG-3790-I mold; K) MPEG-3799-Ia mold; L) MPEG-3832-I mold; M) MPEG-3814-I mold; N) MPEG-3795-Ia countermold; O) MPEG-3785-I mold. Scale bar: 2 mm.



Figure 32- *Schellwienella amazonensis* n. sp., external dorsal valves. A) MPEG-3780-Ic mold; B) MPEG-3860-I mold; C) MPEG-3863-I mold; D) MPEG-3817-d counter mold; E) MPEG-3855-Ia mold; F) MPEG-3855-Ib mold; G) MPEG-3851-I counter mold; H) MPEG-3803-Ib counter mold; I) MPEG-3856-I mold; J) MPEG-3870-I mold; K) MPEG-3827-Ib counter mold; L) MPEG-3874-I counter mold; M) MPEG-3769-Ib counter mold; N) MPEG-3872-I counter mold; O) MPEG-3829-Ic mold. Scale bar: 2 mm.



Figure 33- *Schellwienella amazonensis* n. sp., internal ventral valves. A) MPEG-3812-Ia mold; B) MPEG-3784-I mold; C) MPEG-3762-Ic mold; D) and E) countermold of MPEG-3762-Ic II; F) MPEG-3834-I mold; G) MPEG3808-Ia mold; H) MPEG-3820-I mold; I) MPEG-3807-Ia mold; J) MPEG-3779-I mold; K) MPEG-3831-Ib mold; L) MPEG-3773-I mold; M) MPEG-3817-Ia mold; N) MPEG-3819-I mold; O) MPEG-3817-Ic mold. Scale bar: 2 mm.

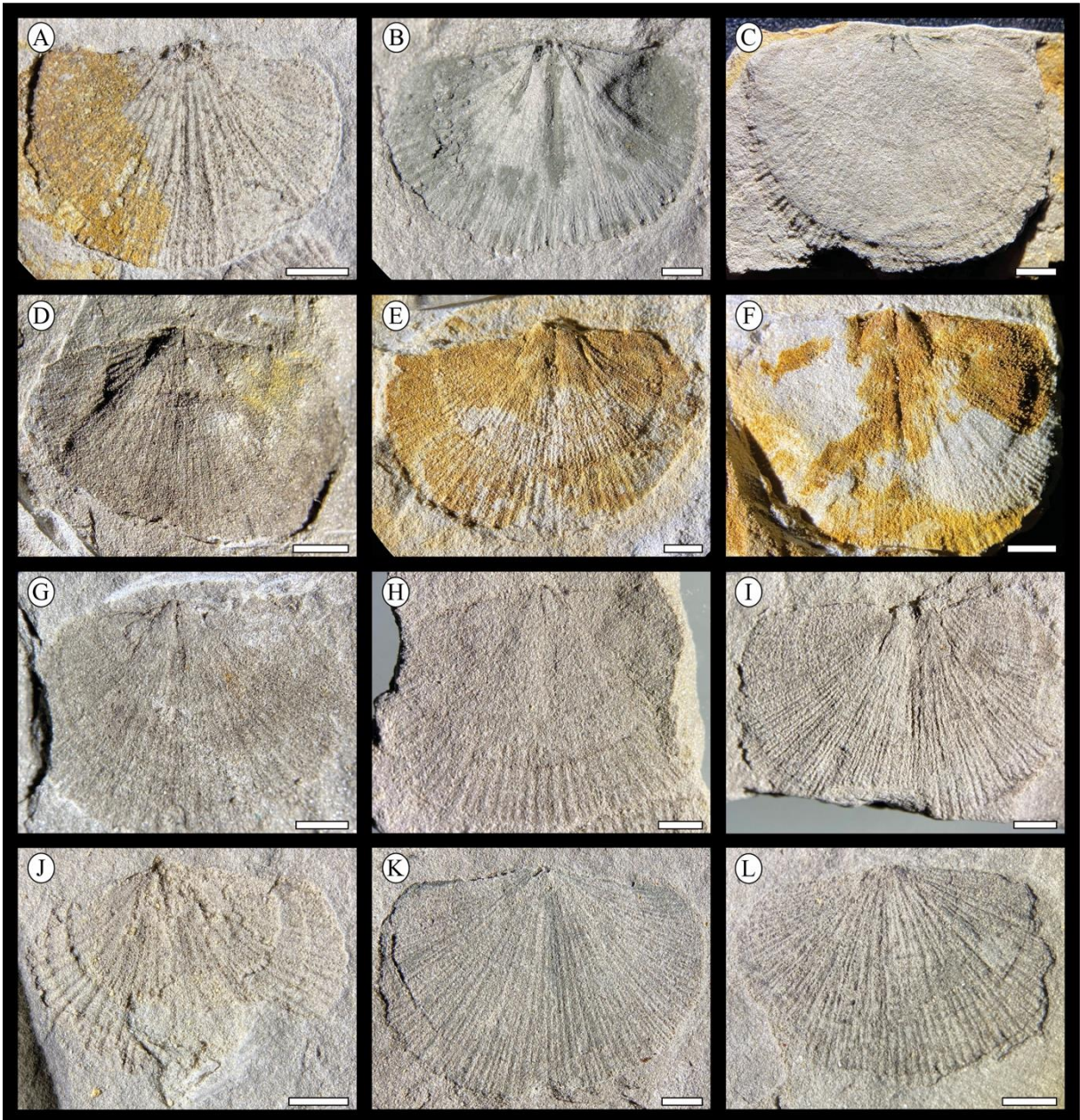


Figure 34- *Schellwienella amazonensis* n. sp., internal dorsal valves. A) MPEG-3793-Ic counter mold; B) MPEG-3873-Ib mold; C) MPEG-3842-I counter mold; D) MPEG-3841-I mold; E) MPEG-3862-I mold; F) MPEG-3843-I mold; G) MPEG-3840-Ib mold; H) MPEG-3854-I mold; I) MPEG-3807-Ib mold; J) MPEG-3793-Ib counter mold; K) MPEG-3852-I counter mold; L) MPEG-3855-Ic counter mold. Scale bar: 2 mm.

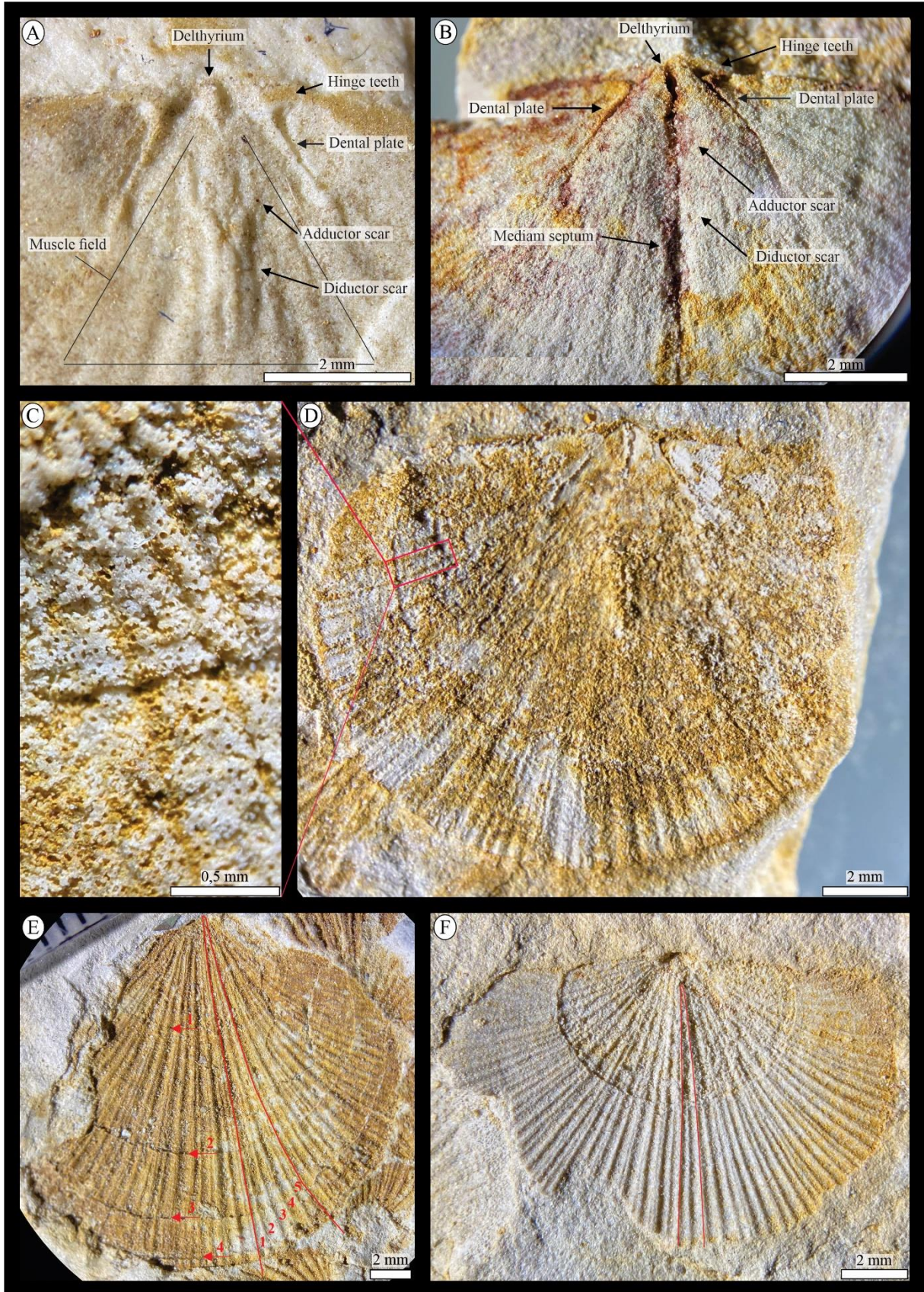


Figure 35- Morphological details of *Schellwiebella amazonenses* n. sp., A) MPEG-3762-Ic internal ventral countermold; B) MPEG-3820-I internal ventral mold; C) and D) MPEG-3808-Ia internal ventral mold; E) MPEG-3802-Ib external ventral countermold; F) MPEG-3816-Ia external ventral mold.

Remarks: The external and internal morphological characters, such as the rectimarginate commissure, growth lines, parvicostellate ornamentation, short and divergent dental plates, muscle field triangular, and ventral muscular impressions divided by the median septum, refer to the diagnosis proposed for the genus *Schellwienella* Thomas, 1910 and to differentiate it from the other Late Paleozoic Orthotetida genera (*Schuchertella* Girty, 1904, *Floweria* Cooper and Dutro, 1982, *Eoschuchertella* Gratsianova, 1974, *Iridistrophia* Havlíček, 1965, *Schuchertellopsis* Maillieux, 1939, *Streptorhynchus* King, 1850, *Xystostrophia* Havlíček, 1965, *Derbyia* Waagen, 1884).

Similarly to what is observed in other Devonian *Schellwienella* species, intraspecific morphological variations were observed in *Schellwienella amazonensis* n. sp., that presents, in some specimens, parvicostellate ornamentation, with costellae that multiplies by bifurcation (Figure 35 F), while others multiply by intercalation, increasing the number of costellae as it gets closer to the commissure, delimited by growth lines (Figure 35 E). Another common variation to *Schellwienella* species is related to shell's outline that, in *Schellwienella amazonensis* n. sp, varies from subcircular to circular.

Comparison with Devonian *Schellwienella* species. — In *Schellwienella justinianoi* Rezende *et al.* 2019, the profile is plano-convex, the median septum occupies 1/3 of the valve length, and the pseudopunctations have a radial distribution. In *Schellwienella clarkei*, the shells are larger (maximum length 27 mm; maximum width 38 mm) the profile ranges from biconvex to plano-convex, the dental plates have a greater divergence angle (120°–70°), and the growth lines are less pronounced. *Schellwienella goldringae* Caster, 1939, the profile is convex-plano or convex-concave, the muscle field is circular with flabellate adductor scars, and the dental plates are weakly marked. Caster (1939) did not describe pseudopunctations or median septum.

Schuchertella sullivanii Morris & Sharpe, 1846, and *Schuchertella sancticrucis* Morris & Sharpe, 1846, were reclassified as *Schellwienella sullivanii* and *Schellwienella sancticrucis* by Caster (1939). Although the author did not review the material, Caster (1939) noted that if the illustrations are reliable, all *Schuchertella* species described for the Devonian of South America and South Africa (*Schuchertella agassizi*, *Schuchertella sancticrucis*, *Schuchertella sullivanii*) would belong to *Schellwienella*. Caster's (1939) justification was that they all have short dental plates; however, he did not consider the other diagnostic characteristics of the genus. Subsequent works followed Caster's classification (Aldis & Edwards 1999, Stone 2010, 2012, 2016, Stone & Rushton, 2013).

Rezende & Isaacson (2021) highlighted the similarity between the ornamentation patterns of the external molds of *Schellwienella sulivani* and *Schellwienella clarkei*, differing only in the shape of the dorsal adductor scar, which is oval in the former and lanceolate in the latter. They suggest this difference might be intraspecific variation but emphasize the need to analyze more specimens. For now, they consider it prudent to accept both as distinct species. Clarke (1913) did not describe pseudopunctations, dental plates, or a median septum, casting doubt on its identification as *Schellwienella sulivani*. The largest specimen analyzed by Clarke (1913) is more than twice the size of the largest specimen of *S. amazonensis* n. sp. In *Schellwienella clarkei*, the dorsal muscular scars are oval, and in the *S. amazonensis* n. sp. are lanceolate.

Schellwienella sancticrucis (Clarke 1913) differs from *S. amazonensis* n. sp. due to its circular outline and simple costellae, which lack bifurcation or intercalation. It has a large flabellate adductor scar. Clarke (1913) stated that the limited and poorly preserved material prevents a thorough comparison with other species. Rezende and Isaacson (2021) emphasize the lack of sufficient material and the need for further studies on *Schellwienella sancticrucis*.

The comparison with *Schellwienella marcidula* Amsden, 1958, *Schellwienella pauli* Gallwitz, 1932, and *Schellwienella percha* Stainbrook, 1947, is primarily limited to external morphology, as the internal valves of these species are scarce and poorly preserved. None of these species exhibit a median septum, cardinal process, or pseudopunctuation. *Schellwienella marcidula*, described by Amsden (1958), has a profile ranging from plano-convex to convexo-concave. In some specimens, the width and length are approximately equal; it has fewer costellae per 5 mm² (9–10) and shorter dental plates. *Schellwienella pauli* differs from *S. amazonensis* n. sp. in having bigger shells (reaching at least 45 mm in width), an oval outline, and a ventribiconvex profile. Its costellae increase only by intercalation, with relatively fewer costellae per 5 mm² (11–13), and the anterior scars are slightly flabellate. *Schellwienella percha* differs from *S. amazonensis* n. sp. in having a subquadrate outline, a plano-convex profile, and costellae that increase only by intercalation.

Comparison with carboniferous *Schellwienella* species. — The species *Schellwienella alternata* Weller, 1914, *Schellwienella burlingtonensis* Weller, 1914, *Schellwienella chouteauensis* Weller, 1914, *Schellwienella crenulicostata* Weller, 1914, *Schellwienella inaequalis* Hall, 1858, *Schellwienella planumbona* Weller, 1914, and *Schellwienella rustica* Stainbrook, 1950 were described based on solely external morphology, making comparison with *S. amazonensis* n. sp. impractical due to the absence of crucial internal features. In

Schellwienella inflata White & Whitfield, 1862, the profile is concavo-convex, the outline is subelliptical, and the ventral muscle scars are flabellate.

Schellwienella radialiformis Demanet, 1934, has larger shells (up to 51 mm width) with a square to sub-square outline. It features fewer costellae per 5 mm² (7–11), and the divergence angles of the dental plates are larger than in *S. amazonensis* n. sp. (78°–93°). *Schellwienella crenistria* Phillips, 1836 has a profile ranging from plano-convex to gently resupinate, with a semicircular outline. It has fewer costellae per 5 mm² (8–10), which increase only by intercalation, and the diductor are flabellate. Both *Schellwienella radialiformis* and *Schellwienella crenistria* are the only Carboniferous species that exhibit pseudopunctations.

In *Schellwienella umbonata* Easton, 1958, the profile is plano-convex, the outline is semicircular, the dental plates are thin and poorly defined, and the median septum is smaller, limited to the muscle field. *Schellwienella ornata* Demanet, 1934 has a ventribiconvex profile, a subquadrate outline, and costellae that increase only by intercalation, with fewer costellae per 5 mm² (6–7). Its dental plates are thin and diverge at a smaller angle (35°–37°). *Schellwienella cheuma* Bassett & Bryant, 2003 differs from *S. amazonensis* n. sp. by having a subcircular to subquadrate outline, dorsobiconvex profile, and multicostellate ornamentation, with fewer costellae per 5 mm² (12). It also has a weaker and shorter median septum, and dental plates with slightly smaller divergence angles compared to *S. amazonensis* n. sp.

Orthotetida in the Devonian from the Amazonas Basin. — The first identification of Orthotetida in the Devonian of the Amazonas Basin was carried out by Rathbun (1874) when analyzing specimens from the Ererê Formation. Rathbun (1874) proposed the species *Streptorhynchus agassizi*, describing it with a biconvex profile and a circular to subelliptical outline; the impressions of the dental plates are visible only in the hinge area beside the fissure, appearing as shallow depressions that do not extend into the valve; the cardinal process is small and thin, with two small processes on each side projecting backward; the socket plates are short, thin, and highly divergent, forming an angle of about 135°; the ornamentation of the valves consists of costellae that increase in number by intercalation or bifurcation. Clarke (1913) relocated *Streptorhynchus agassizi* to the genus *Schuchertella* based on the shapes of its costellae and size, flabelliform ventral muscular impressions. Carvalho (1972) identified specimens of *Streptorhynchus agassizi* from the Maecuru and Ererê formations when analyzing only ventral valves; the report of short and shallow dental plates complements the description made by Rathbun (1874). Carvalho (1972) compared the material studied only with the work of Rathbun (1874), ignoring the reallocation made by Clarke (1913). Copper (1977) cited the

occurrence of *Schellwienella agassizi* in the Devonian of the Amazonas Basin (Maecuru and Ererê formations); however, the author did not provide any description, discussion, or illustration of the material, nor did he justify the criteria used to classify it. Rezende & Isaacson (2021) reviewed specimens of *Schuchertella agassizi* from the Paraná Basin (Ponta Grossa and São Domingos formations) and Bolivia (Icla, Belén, Gamoneda, and Huamampampa formations) and proposed a species *Schellwienella clarkei*; they report the need to review *Schuchertella agassizi* from the Amazonas Basin.

The specimens of *Schuchertella agassizi* from the Maecuru and Ererê formations, housed in the paleontological collection from the MPEG (Figure 36 A-I), are not well-preserved. Despite being fragmented, the valves of *Schuchertella agassizi* are higher and bigger than those of *S. amazonensis* n. sp. The dorsal valve has a rounded and more convex umbo when compared to the ventral valve. The costellae multiply by bifurcation and intercalation; the growth lines, weakly marked, intercalate the costellae near the anterior margin, occurring less frequently compared to *S. amazonensis* n. sp. The socket plates are short, well-marked, and divergent, with a divergence angle of 137.94° . There are no internal ventral valves in the analyzed material. Though the similarities to *Schellwienella clarkei*, the absence of internal morphological characteristics, such as dental plates, median septum, bilobed cardinal process, muscle scars, and pseudopunctations, prevents the reclassification of *Schuchertella agassizi*.

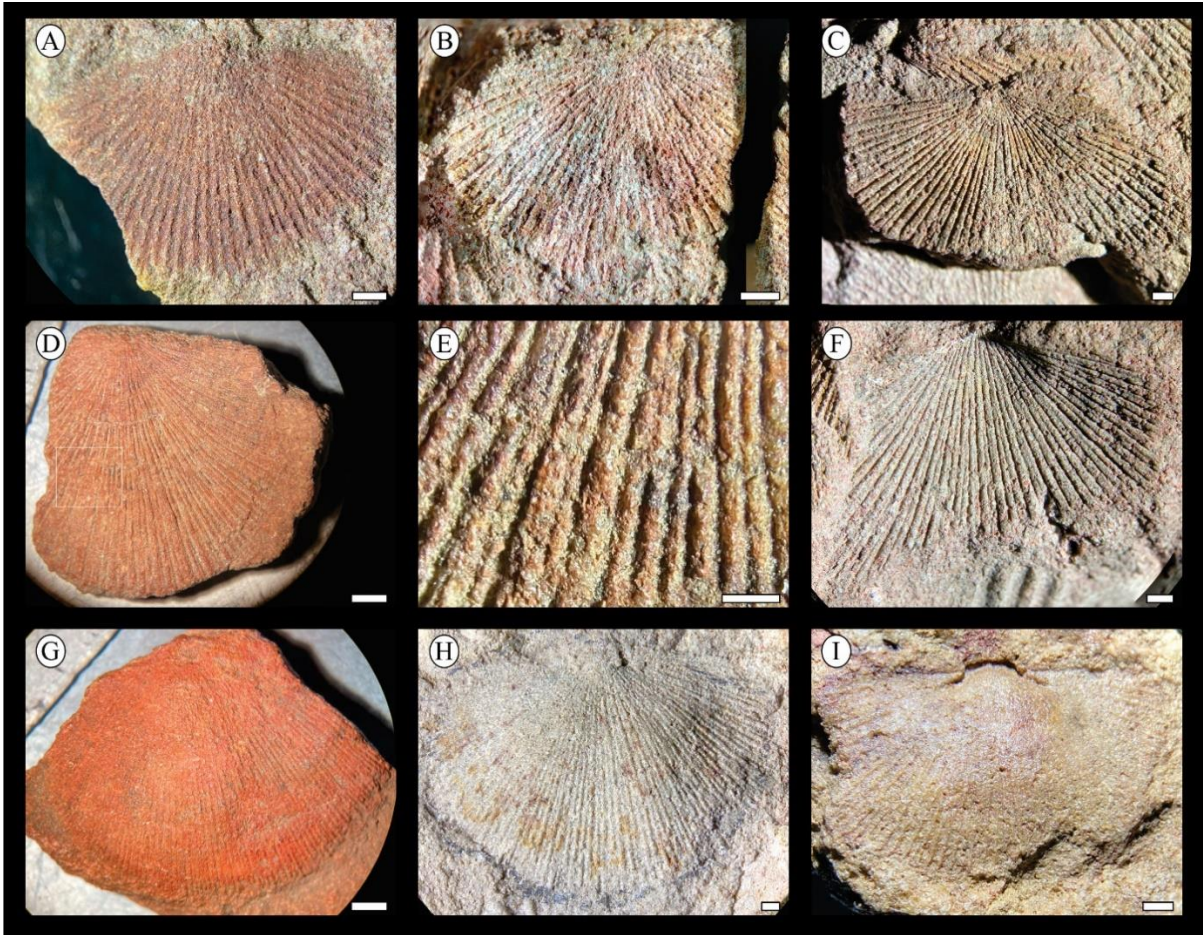


Figure 36- *Schuchertella agassizi* from Maecuru and Ererê formations. A) MPEG-0830-I external ventral mold; B) MPEG-0159-I external ventral mold; C) MPEG-0159-II external ventral mold; D) MPEG-029-I external ventral mold; E) MPEG-029-I ornamentation deltails; F) MPEG-159-III external dorsal mold; G) MPEG-026-I external dorsal counter mold; H) MPEG-0214-I internal dorsal counter mold; I) MPGE-053-I internal dorsal counter mold. Maecuru Formation: MPEG-029-I, MPEG-026-I, and MPGE-053-I; Ererê Formation MPEG-0830-I, MPEG-0159-I, MPEG-0159-II, MPEG-159-III, and MPEG-0214-I. Scale bar: 2 mm.

6.5 PALEOBIOGEOGRAPHIC CONSIDERATIONS

Schellwienella has a stratigraphic distribution that ranges from the Lower Devonian to the Lower Carboniferous (Williams *et al.* 2000). The oldest records include the species *S. marcidula* from the Bois d'Arc Formation (Lochkovian), USA (Amsden 1958), and now *S. amazonensis* n. sp. from the Manacapuru Formation (Lochkovian), Brazil. During the Devonian, seven other species were present: *S. clarkei* (Ponta Grossa and São Domingos formations – Paraná Basin; Icla, Belén, Gamoneda, and Huamampampa – Subandina and Chaco basins), *S. goldringae* (Floresta Formation – Llanos Basin), *S. justinianoi* (Longá Formation – Parnaíba Basin), *S. pauli* (Set L from the Kowala quarry – Lublin Basin), *S. percha* (Percha Formation – Illinois Basin), *S. sancticrucis* (São Domingos Formation, Paraná Basin), and *S. sullivanii* (Ponta Grossa Formation – Paraná Basin; Fox Bay Formation – Falkland Islands; Bokkeveld Beds – Cape Basin) (Morris & Sharpe 1846, Clarke 1913, Caster 1939, Stainbrook

1947, Sanchez & Benedetto 1983, Biernat 1966, Halamski & Balinski 2009, Rezende *et al.* 2019, Rezende & Isaacson 2021).

Despite being considered a cosmopolitan genus, during the Devonian, a significant portion of its occurrences was concentrated in Gondwana (Brazil, Bolivia, Colombia, Falkland Islands, South Africa, and Venezuela), where it inhabited siliciclastic marine environments. In this region, the genus established itself during the Lochkovian in the Amazonas Basin, the same stage at which it is found in Oklahoma (USA) (Amsden 1958). It is difficult to determine whether the cosmopolitan larvae migrated first from Laurussia (Bois d'Arc Formation) to Gondwana (Manacapuru Formation) or vice versa (Figure 37). The first hypothesis is most likely, given that during the Silurian, environmental conditions in Gondwana were still quite cold; the main Paleozoic basins of Gondwana are located between the polar latitudes (60° - 90°S); remnants of the Ordovician-Silurian Glaciation are recorded in the diamictites of the Pitinga (Amazonas Basin) and Ipu (Parnaíba Basin) formations (Cunha *et al.* 2007, Barrera *et al.* 2020). Brachiopod occurrences were concentrated in Laurentia, as evidenced by *Orbiculoidea* (Finnegan *et al.* 2011, Zhang *et al.* 2018, Corrêa & Ramos 2021).

As Gondwana migrated north during the Devonian-Carboniferous, *Schellwienella* expanded its distribution. In the Pragian, the species of this genus occupied the southwest and south of Gondwana (Bolivia, Paraná Basin, South Africa, and the Falkland Islands) in the paleobiogeographic region known as the Malvinohosan Realm (Boucot 1975, Boucot *et al.* 2001, Penn-Clarke & Harper 2020). This realm included subpolar and polar regions (60° S – 90° S) with cold waters (Boucot *et al.* 2001, Penn-Clarke & Harper 2020). Later, during the Emsian-Givetian, the genus spread to a region further from the South Pole, Northwestern Gondwana, specifically the Llanos Basin (Colombia and Venezuela). By the Famennian, the remaining species inhabited regions near low latitudes in the USA, Poland, and Brazil (Parnaíba Basin).

In the Carboniferous, the genus increased the number of species compared to the previous period. Twenty species are known: *S. alternata* (Burlington limestone - Valley Basin), *S. aspis* (Feltrim Limestone Formation – Dubin Basin), *S. australis* (Yindagindy Formation - Carnarvon Basin), *S. burlingtonensis* (Burlington limestone - Valley Basin), *S. cheuma* (Friars Point Limestone Formation – South-East Wales), *S. chouteauensis* (Chouteau limestone – Valley Basin), *S. crenistria* (Hutk Formation - mountains N of Kerman, southeastern Iran; High Tor Limestone - South Wales), *S. crenulicostata* (Horizon Kinderhook – Valley Basin), *S. inaequalis* (Horizon Kinderhook – Valley Basin), *S. inflata* (Horizon Kinderhook – Valley Basin), *S. izirii* (Arisu and Odaira formations - South Kitakami Belt), *S.*

minilyensis (Langfield Group – Bonaparte Gulf Basin) , *S. ornata* (Visé Formation - Namur–Dinant Basin), *S. planumbona* (Horizon Kinderhook – Valley Basin), *S. radialiformis* (Tournai Formation - Namur–Dinant Basin), *S. radialis* (Arisu and Odaira formations - South Kitakami Belt) , *S. rustica* (Aplington Formation - northwest Iowa), *S. scotica* (Limestone Group, Scotland), *S. umbonata* (Cratonic platform of Sonora), and *S. weaberensis* (Langfield Group – Bonaparte Gulf Basin) (Weller 1914, Smyth 1930, Stainbrook 1950, Minato 1951, Easton 1958, Thomas 1971, Gratsianova 1974, McIntosh 1974, Roberts & Oversby 1974, Yugan & Waterhouse 1986, Wendt *et al.* 2002, Bassett & Bryant 2006, Mottequin & Simon 2017, Tazawa 2020).

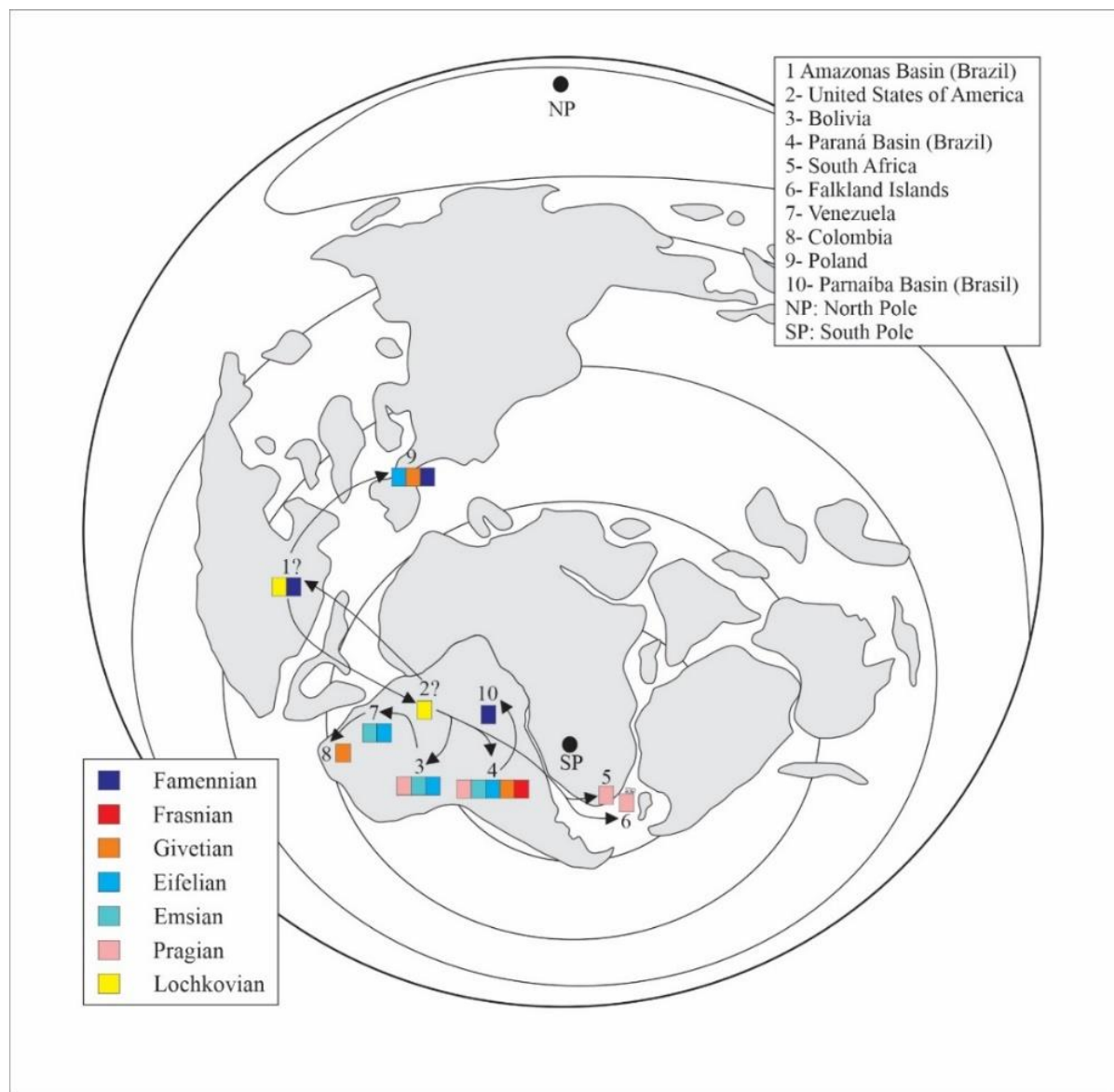


Figure 37- Distribution of the *Schellwienella* throughout the Devonian. Base map modified from Scotese *et al.* (1999), Boucot *et al.* (2013), Videira-Santos & Scheffler (2024).

Throughout the Devonian, *Schellwienella* migrated between temperate, subpolar, and polar regions. In contrast, during the Carboniferous, the genus had a shorter stratigraphic range, confined to the Tournaisian–Viséan interval, with a preference for warm, carbonate environments near low-latitude regions (Figure 38). Seven of the eleven occurrence localities (Illinois – USA, New Mexico – USA, England, Wales, Ireland, Belgium, and Russia) are located in the Laurussia supercontinent, near the equator. The three localities farthest from the 0° latitude are Iran, Northwest China, and Australia, which were influenced by warm surface currents, despite the distance.

During the Mississippian, latitudinal gradients controlled the distribution of marine benthic faunas, which were closely related to local temperatures. These factors account for the geographical distribution of *Schellwienella* during the Tournaisian–Viséan interval (Ross & Ross 1988, Torsvik & Cocks 2016).

The extinction of the genus is probably related to environmental factors such as temperature and oxygen availability. During the middle Carboniferous, the planet experienced a cooling period. Although Gondwana was extensive, Carboniferous glacial events did not impact all regions equally (Davydov *et al.* 2012). In the early Serpukhovian, there is evidence of glaciation in Australian successions (Fielding *et al.* 2008). Similarly, glaciogenic rocks from the Bashkirian have been identified in Iran (Davydov *et al.* 2012). *Schellwienella* previously inhabited both of these regions.

Due to the increase in glaciation and the formation of extensive coal deposits that characterized the Carboniferous, there was a significant change in atmospheric carbon dioxide concentrations. These concentrations decreased from about 1,500 parts per million (ppm) in the Lower Carboniferous to approximately 350 ppm in the Middle Carboniferous (Berner 1997, Torsvik & Cocks 2016).

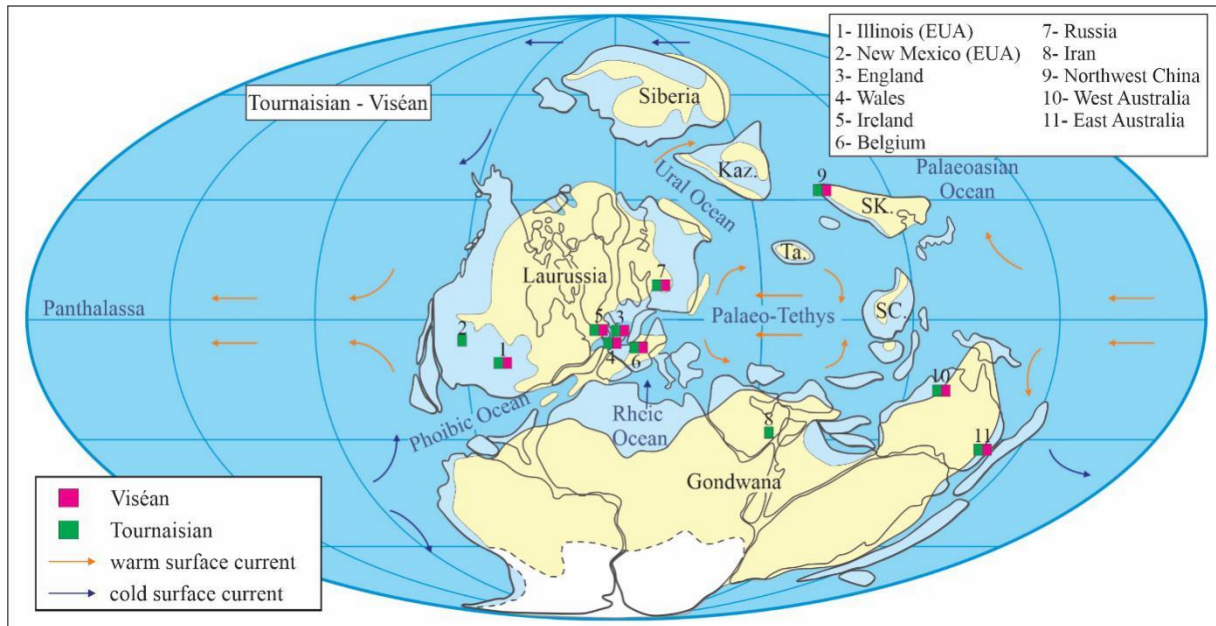


Figure 38- Distribution of the *Schellwienella* throughout the Carboniferous. Base map modified from Scotese (2004), Metcalfe (2011), and Shi *et al.* (2016). Ocean surface circulation patterns modified from Smith & Read (2000), Hüneke (2006), and Shi *et al.* (2016).

6.6 CONCLUSION

The taxonomic study of the Orthotetida from the Manacapuru Formation (Lochkovian) has led to the identification of a new species, *Schellwienella amazonensis* n. sp.. This species and *S. marcidula* from the Bois d'Arc Formation (Lochkovian), USA, represent the oldest genus records. The Maecuru and Ererê formations (Amazonas Basin) have records of “*Schuchertella*” *agassizi*. In the Paraná Basin, this species has been reviewed, and a new species, *Schellwienella clarkei*, has been proposed. A revision of “*Schuchertella*” *agassizi* in the Amazonas Basin is needed, involving a thorough analysis of the internal ventral and dorsal valves. Until this review is completed, *S. amazonensis* n. sp. is considered the only occurrence of the genus in the Amazonas Basin.

In the Devonian, *Schellwienella* is found throughout all stages of the period, with most of its occurrences concentrated in Gondwana, inhabiting siliciclastic marine environments and transitioning between temperate, subpolar, and polar regions. In the Carboniferous, the genus had a shorter stratigraphic range, confined to the Tournaisian – Viséan interval, and showed a preference for warm environments and carbonate platforms near low-latitude regions.

ACKNOWLEDGMENTS

The authors would like to thank the Museu Paraense Emilio Goeldi for providing the necessary laboratory infrastructure and access to the paleontological collection. The Federal

University of Pará provided support for this research through the PPGG-UFPA. This work was supported by the CAPES (financing code 001); and the CNPQ (productivity fellowships grants 307424/2019–7 and 305031/2022-8 to M.I.F.R).

REFERENCES

Aldiss DT & Edwards EJ. 1999. The Geology of the Falkland Islands. British Geological Survey Technical Report WC/99/10: 1-135.

Amsden TW. 1958. Stratigraphy and paleontology of the Hunton Group in the Arbuckle Mountain Region. Part II - Haragan articulate brachiopods. Oklahoma Geological Survey Bulletin 78: 1–144.

Barrera IAR, Nogueira ACR, Bandeira J. 2020. The Silurian glaciation in the eastern Parnaíba Basin, Brazil: paleoenvironment, sequence stratigraphy and insights for the evolution and paleogeography of West Gondwana. *Sedimentary Geology*, 406: 105714.

Bassett MG & Bryant C. 2006. A Tournasian Brachiopod fauna from south-east Wales. *Palaeontology*. 49: 485–535.

Benedetto JL. 1984. Les Brachiopodes Devoniens de la Sierra de Perija (Venezuela): Biostratigraphie du Paléozoïque, 1. Université Bretagne Occidentale, France. p. 1-191.

Berner RA. 1997. The rise of plants and their effect on weathering and atmospheric CO₂. *Science*. 276: 544–546.

Biernat G. 1966. Middle Devonian Brachiopods of the Bodzentyn Syncline (Holy Cross Mountains, Poland). *Palaeontologia Polonica*. 17:1-162.

Boucot AJ, Johnson JG, Talent JA. 1969. Early Devonian Brachiopod Zoogeography: Geological Society of America Special Paper. 119: 1-113. <https://doi.org/10.1130/SPE119>

Boucot AJ, Rowell AJ, Racheboeuf P, Pereira E, Melo JHG, Siqueira LP. 2001. Position of the Malvinokaffric Realm's northern boundary (Early Devonian) based on newly discovered brachiopods from the Parecis Basin (Brazil). *Journal of the Czech Geological Society*. 46: 109-120.

Boucot AJ, Xu C, Scotese CR, Morley RJ. 2013. Phanerozoic Paleoclimate: An Atlas of Lithologic Indicators of Climate. Society for Sedimentary Geology. 11:1-30.

Boucot AJ. 1975. Developments in Paleontology and Stratigraphy 1: Evolution and Extinction Rate Controls. Elsevier Scientific Publishing Company, Amsterdam. 1-427.

Caputo MV. 1984. Stratigraphy, tectonics, paleoclimatology and paleogeography of northern basins of Brazil. Califórnia, Universidade da Califórnia.

Carozzi AV, Pamplona HRP, Castro JC, Contreiras CJA. 1973. Ambientes Depositionais e Evolução Tecto sedimentar da Seção clástica Paleozoica da Bacia do Médio Amazonas. In: Anais do 28° Congresso Brasileiro de Geologia. Aracaju. 279–314.

- Carvalho RG. 1975. Braquiópodes Devoniano da Bacia do Amazônica, orthida, stophomenida, spiriferida e terebratulida. *Boletim do Museu Paraense Emílio Goeldi, Geologia*. 21: 1-22.
- Carvalho RGD. 1972. Braquiópodes devonianos da Bacia do Amazonas. São Paulo, SP. Tese de Doutorado. Instituto de Geociências, Universidade de São Paulo, 1-140.
- Caster KE. 1939. A Devonian fauna from Colombia: *Bulletins of American Paleontology*. Ithaca. 24: 1–218.
- Clarke JM. 1899. A fauna siluriana superior do Rio Trombetas: Estado do Pará, Brazil. *Archivos do Museu Nacional*. 1-32
- Clarke JM. 1913. Fósseis devonianos do Paraná. *Monographias do Serviço Geológico e Mineralógico do Brasil, Rio de Janeiro*. 1: 1-353.
- Cooper GA & Dutro JT. 1982. Devonian brachiopods of New Mexico. *Bulletins of American Paleontology* 82-83: 1-215.
- Cooper GA & Grant RE. 1974. Permian Brachiopods of West Texas, II. *Smithsonian Contributions to Paleobiology*. 15: 233–793.
- Copper P. 1977. Paleolatitudes in the Devonian of Brazil and the Frasnian-Famennian mass extinction. *Paleogeography, Palaeoclimatology, Palaeoecology*. 21: 165-207.
- Corrêa LFA & Ramos MIF. 2021. Discinoids (Brachiopoda: Lingulata) from the upper Manacapuru Formation (Early Devonian), south border of Amazonas Basin, Brazil. *Journal of South American Earth Sciences*. 105: 102960. <https://doi.org/10.1016/j.jsames.2020.102960>
- Corrêa LFA & Ramos MIF. 2023. Relationships between brachiopod fauna (Lochkovian–Frasnian) from northwest Gondwana (Amazonas Basin) and environmental changes during the Devonian. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 629: 111803.
- Cunha PRC, Gonzaga FG, Coutinho LFC, Feijó FJ. 1994. Bacia do Amazonas. *Boletim de Geociências da PETROBRAS*. 8: 47-55.
- Cunha PRC, Melo JHG, Silva OB. 2007. Bacia do Amazonas. *Boletim de Geociências – Petrobras*. 15: 227–251.
- Cunha PRC. 2000. Análise Estratigráfica dos sedimentos Eo/Mesodevonianos da porção ocidental da Bacia do Amazonas sob a ótica da estratigrafia de Sequências no interior cratônico. Porto Alegre, UFRGS.
- Davydov VI, Korn DK, Schmitz MD, Gradstein FM, Hammer Ø. 2012. The carboniferous period. In *The geologic time scale*. 603-651.
- Demant F. 1934. Les brachiopodes du Dinantien de la Belgique. Premier volume. *Atremata, Neotremata, Protremata (pars)*. Mémoires du Musée royal d’Histoire naturelle de Belgique. 61:1-116.
- Derby OA. 1877. Contribuição para a geografia da região do Baixo Amazonas. *Archivos do Museu Nacional*. 3: 77-104.

- Dowding EM, Ebach MC, Mavrodiev EV. 2021. Validating marine Devonian biogeography: a study in bioregionalization. *Palaeontology*, 65(1): 12578. <https://doi.org/10.1111/pala.12578>
- Easton W. H. 1958. Mississippian fauna in northwestern Sonora, Mexico. *Smithsonian Miscellaneous Collections*. 119(3): 1-99.
- Fielding CR, Frank TD, Birgenheier LP, Rygel MC, Jones AT, Roberts J. 2008. Stratigraphic imprint of the late Palaeozoic ice age in eastern Australia: A record of alternating glacial and nonglacial climate regime. *Journal of the Geological Society*. 165: 129-140.
- Finnegan S, Bergmann K, Eiler JM, Jones DS, Fike DA, Eisenman I, Hughes NC, Tripathi AK, Fisher WW. 2011. The magnitude and duration of late ordovician-early Silurian glaciation. *Science*. 331(6019): 903-906. doi: 10.1126/science.1200803
- Fonseca VMM. 2004. Chonetoidea (Brachiopoda) do Devoniano Médio das Bacias do Amazonas e Parnaíba, Brasil. *Archivos do Museu Nacional*. 62: 193-215.
- Gallwitz H. 1932. Die Fauna des deutschen Unterkarbons. 3. Teil. Die Brachiopoden, 3 Teil: Die Orthiden, Strophomeniden und Choneten des Unteren Unterkarbons (Etröeungt). *Abhandlungen der Preußischen Geologischen Landesanstalt, Neue Folge*. 141: 75–131.
- Girty GH. 1904. New molluscan genera from the Carboniferous. *United States National Museum Proceedings* 27: 721–736.
- Grahn Y & Melo JHG. 1990. Bioestratigrafia dos quitinozoários do Grupo Trombetas nas faixas marginais da Bacia do Amazonas. Rio de Janeiro: PETROBRAS/CENPES/DIVEX/SEBIPE. Report produced for the Eletrobras Eletronort. 1-43.
- Grahn Y. 2005. Silurian and lower devonian chitinozoan taxonomy and biostratigraphy of the Trombetas group, Amazonas Basin, northern Brazil. *Bulletin of Geosciences*. 80(4): 245–276.
- Gratsianova RT. 1974. ‘Schuchertellas’ of the Early and Middle Devonian in the south of western Siberia. *Trudy Instituta geologii i geofiziki, Akademikila nauk SSSR*. 84: 77–87.
- Halamski AT & Baliński A. 2009. Latest Famennian brachiopods from Kowala, Holy Cross Mountains, Poland. *Acta Palaeontologica Polonica*. 54(2): 289-306.
- Hall J. 1858. Paleontology. In: J. Hall and J. D. Whitney (eds) *Report on the Geological Survey of the State of Iowa; embracing results of investigations made during portions of the years 1855–1857*. Iowa Geological Survey. 473–724
- Harper DAT, Popov LE, Holmer LE. 2017. Brachiopods: origin and early history. *Palaeontology*. 60(5): 609-631. <https://doi.org/10.1111/pala.12307>
- Havlíček V. 1965 Superfamily Orthotetacea (Brachiopoda) in the Bohemian and Moravian Palaeozoic. *Vestník Ústředního ústavu geologického* 40(4): 1–294.
- Hüneke, H., 2006. Erosion and deposition from bottom currents during the Givetian and Frasnian: Response to intensified oceanic circulation between Gondwana and Laurussia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 234, 146–167.

Janvier P & Melo JHG. 1988. Acanthodian fish remains from the upper silurian or lower devonian of the Amazonas Basin, Brazil. *Palaeontology* 31(3): 771–777.

Katzer F. 1897. Das Amazonas-Devon und seine Beziehungen zu den anderen Devon-gebieten der Erde. Verlag der Königl. Böhmisches Gesellschaft der Wissenschaften. 47:1-50.

Kegel W. 1953. Contribuição para o estudo do Devoniano da Bacia do Parnaíba [Contribution to Parnaíba Basin Devonian study]. Rio de Janeiro, Departamento Nacional da Produção Mineral, Divisão de Geologia e Mineralogia. Located at: Companhia de Pesquisa de Recursos Naturais, Rio de Janeiro. Boletim 14.

King W. 1850. A Monograph of the Permian Fossils of England. *Palaeontographical Society Monograph* 3:1-258.

Klemme HD. 1980. Petroleum basins – classification and characteristics. *Journal of Petroleum Geology*. 3(2): 187–207. <https://doi.org/10.1111/j.1747-5457.1980.tb00982.x>

Lange FW. 1954. Paleontologia do Paraná [Paraná Palaeontology]. *In*: Lange FW, editor. Volume comemorativo do 1º centenário do Estado do Paraná. Curitiba, Brasil: Comissão de Comemorações do Centenário do Paraná. p. 1–107.

Maillieux E. 1939. La faune des schistes de Barvauxsur Ourthe (Frasnien Supérieur). *Musée Royale d'Histoire Naturelle de Belgique, Bulletin*. 15(53):1–8.

Matsuda NS, Winter WR, Wanderley Filho JR, Cacula ASM. 2010. O Paleozoico da borda sul da Bacia do Amazonas, Rio Tapajós - Estado do Pará. *Boletim de Geociências da PETROBRAS*. 18(1): 123-152.

McIntosh MJ. 1974. Some Scottish Carboniferous davidsoniacean brachiopods. *Scottish Journal of Geology*. 10:199-222.

Melo JHG. 1985. A Província Malvinocáfrica no Devoniano do Brasil [M. Sc. Thesis]: Rio de Janeiro, Universidade Federal do Rio de Janeiro. p. 1-890.

Melo JHG. 1988. The Malvinokaffric Realm in the Devonian of Brazil. *In*: McMillan NJ, Embry AF, Glass DJ. (Eds): *Devonian of the world*. Calgary. Canadian Society of Petroleum Geologists Memoir. 14(1): 669– 703.

Metcalfe, I., 2011. Tectonic framework and Phanerozoic evolution of Sundaland. *Gondwana Research* 19, 3–21.

Minato M. 1951. On the Lower Carboniferous fossils of the Kitakami Massif, northeast Honshu, Japan. *Journal of the Faculty of Science, Hokkaido University. Geology and Mineralogy*. 7(4):355-382.

Morris J & Sharpe D. 1846. Description of eight species of Brachiopodous shells from the Palaeozoic rocks of the Falkland Islands. *Quarterly Journal of the Geological Society of London*. 2: 274–278.

Mottequin B & Simon E. 2017. New insights on Tournaisian–Visean (Carboniferous, Mississippian) athyridide, orthotetide, rhynchonellide, and strophomenide brachiopods from southern Belgium. *20.2.28A*: 1-45. <https://doi.org/10.26879/758>

- Penn-Clarke CR & Harper DAT. 2020. Early-Middle Devonian brachiopod provincialism and bioregionalization at high latitudes: A case study from southwestern Gondwana. *Geological Society of America Bulletin*, 133(3-4): 819-836. <https://doi.org/10.1130/B35670.1>
- Phillips J. 1836. *Illustrations of the geology of Yorkshire. Part II: The Mountain Limestone.* London. Palaeozoic rocks of Cornwall, Devon and West Somerset. London. 1-256.
- Quadros LP. 1985. *Distribuição bioestratigráfica dos Chitinozoa e Acritarchae na Bacia do Amazonas.* Ph.D. Thesis, Universidade Federal do Rio de Janeiro.
- Rathbun R. 1874 – On the devonian Brachiopoda of Ererê, Province of Pará, Brazil. *Buffalo Society of Natural Sciences, Bulletin*, Buffalo. 1: 236-261.
- Rathbun R. 1878. The Devonian Brachiopoda of the Province of Pará, Brazil. *Boston Society of Natural History*. 20: 14-39.
- Rezende JMP & Isaacson PE. 2021. *Schellwienella clarkei* (Orthotetida, Brachiopoda): a new species from the Devonian of the Paraná Basin, Brazil. *Journal of Paleontology*. 95(4): 733-747. doi.org/10.1017/jpa.2020.113
- Rezende JMP, Ponciano LCMO, Brett CE. 2019. Brachiopod fauna from Longá Formation (Upper Devonian), State of Piauí, NE Brazil. *Historical Biology*. 33(8): 1-11. doi.org/10.1080/08912963.2019.1692343.
- Roberts J & Oversby BS. 1974. The Lower Carboniferous geology of the Rouchel district, New South Wales. *Bulletin (Australia. Bureau of Mineral Resources, Geology and Geophysics)*. 147:1-93.
- Rocha, P.F., Silveira, R.R., Barbosa, R.C.M., 2019. Age and palaeoenvironments of the Manacapuru formation, presidente figueiredo (AM) region, lochkovian of the Amazonas Basin. *Brazilian Journal of Geology*. 49(4): 1-12.
- Ross CA & Ross JRP. 1988. Late Paleozoic transgressive-regressive deposition. In: Wilgus CK, Hastings BS, Kendall CG, Posamentier HW, Ross CA, Van-Wagoner JC. *Sea-Level Changes-Na Integrated Approach*, 42. Society for Sedimentary Geology, Special Publication. 227-247.
- Sanchez TM & Benedetto JL. 1983. Paleoecologia, comunidades bentônicas y sucesión paleoambiental en el Grupo Rio Cachiri, Devonico, Sierra de Perija, Venezuela. *Ameghiniana*. 20(3-4): 163-198.
- Schlotheim EF. 1820. Die Petrefactenkunde auf ihren jetzigen Standpunkte durch die Beschreibung seiner Sammlung versteinerten und fossiler Überreste des Thierund Pflanzen-Reichs der Vorwelt erläutert. 1-437.
- Scotese CR, Boucot AJ, McKerrow WS. 1999. Gondwanan palaeogeography and palaeoclimatology. *Journal of African Earth Sciences*. 28(1): 99-114. [https://doi.org/10.1016/S0899-5362\(98\)00084-0](https://doi.org/10.1016/S0899-5362(98)00084-0)
- Scotese CR. 2004. A continental drift flipbook. *Journal of Geology* 112, 729-741

- Shi GR, Chen ZQ, Lee S, Zhan L P. 2016. Early Carboniferous spiriferoid brachiopods from the Qaidam Basin, Northwest China: Taxonomy, biostratigraphy and biogeography. *Palaeoworld*. 25(4): 581-599.
- Smith LB & Read JF. 2000. Rapid onset of late Paleozoic glaciation on Gondwana: Evidence from Upper Mississippian strata of the Midcontinent, United States. *Geology* 28, 279–282.
- Smyth LB. 1930. The Carboniferous rocks of Hook Head, County Wexford. *Proceedings of the Royal Irish Academy (section B)*. 39:523-566.
- Souza VS & Nogueira ACR. 2009. Manaus-Presidente Figueiredo (AM), borda norte da Bacia do Amazonas: um guia para excursão de campo. *Revista Brasileira de Geociencias*. 39(1): 16–29.
- Stainbrook M A. 1947. Brachiopoda of the Percha Shale of New Mexico and Arizona. *SEPM Society for Sedimentary Geology: Journal of Paleontology*. 21(4): 297- 328.
- Stainbrook M A. 1950. Brachiopoda and Stratigraphy of the Aplington Formation of Northern Iowa. *SEPM Society for Sedimentary Geology: Journal of Paleontology*. 24(3): 365-385.
- Stemans P, Rubinstein C, Melo JHG. 2008. Siluro-Devonian miospore biostratigraphy of the Urubu River area, western Amazonas Basin, northern Brazil. *Geobios* 41(2): 263–282.
- Stigall Rode AL. 2005. Systematic revision of the middle and late Devonian Brachiopods *Schizophoria* (*Schizophoria*) and ‘*Schuchertella*’ from North America. *Journal of Systematic Palaeontology*. 3: 133–167.
- Stone P & Rushton A. 2013. Charles Darwin, Bartholomew Sullivan, and the geology of the Falkland Islands: unfinished business from an asymmetric partnership. *Earth Sciences History*. 32: 156–185.
- Stone P. 2010. The geology of the Falkland Islands. *Deposits Magazine*. 23: 38–43.
- Stone P. 2012. Devonian and Permian fossils from the Falkland Islands in the biostratigraphy collection of the British Geological Survey. *British Geological Survey Open File Report*. OR/12/040. 1-27.
- Stone P. 2016. Geology reviewed for the Falkland Islands and their offshore sedimentary basins, South Atlantic Ocean. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*. 106(2): 115–143.
- Tazawa JI. 2020. Early Carboniferous (Mississippian) brachiopods from the Shittakazawa, Arisu and Odaira formations, South Kitakami Belt, Japan. *Memoir of the Fukui Prefectural Dinosaur Museum*. 19: 11–88
- Thomas GA. 1971. Carboniferous and early Permian brachiopods from Western and Northern Australia. *Bureau of Mineral Resources, Geology and Geophysics, Bulletin*. 39: 1–159.
- Thomas I. 1910. The British Carboniferous Orthotetinae. *Memoirs of the Geological Survey of Great Britain, Palaeontology*. 1: 83–134.

Tomassi HZ, Almeida CM, Ferreira BC, Brito MB, Barberi M, Rodrigues GC, Teixeira SP, Capuzzo JP, Gama-Júnior JM, Santos MGKG. 2015a. Preliminar results of paleontological salvage at Belo Monte Powerplant construction. *Brazilian Journal of Biology*. 75(3): 277-289. <https://doi.org/10.1590/1519-6984.1714BM>

Tomassi HZ, Ferreira BC, Almeida CM, Barberi M, Brito MB, Ramos LS. 2015b. Relatório técnico Final do Programa de Salvamento do Patrimônio Paleontológico da Usina Hidrelétrica de Belo Monte. *TERRAGRAPH Paleontologia*. Belém. 1: 1–50.

Torsvik TH & Cocks LRM. 2013. Gondwana from top to base in space and time. *Gondwana Research*. 24: 999-1030. <https://doi.org/10.1016/j.gr.2013.06.012>

Torsvik TH & Cocks LRM. 2016. *Earth history and paleogeography*. Cambridge University Press. 1–317. <https://doi.org/10.1017/9781316225523>.

Videira-Santos R & Scheffler SM. 2024. The *Tropidoleptus carinatus* controversy: Did this brachiopod occur in the Devonian of the Paraná Basin, Brazil?. *Journal of Paleontology*. 97(6): 1192-1205.

Waagen WH. 1884. Salt Range fossils, Part 4 (2), Brachiopoda. *Palaeontologia Indica*. 13(4): 547–610.

Wanderley Filho JR, Melo JHG, Fonseca VMM, Machado DMC. 2005. Bacias sedimentares brasileiras: bacia do Amazonas. *Phoenix*. 7(82): 1–6.

Weller S. 1914. The Mississippian Brachiopoda of the Mississippian Valley Basin. 1:1-508

Wendt J, Kaufmann B, Belka Z, Farsan N, Bavandpurs AK. 2002. Devonian/Lower Carboniferous stratigraphy, facies patterns and palaeogeography of Iran Part I. Southeastern Iran. *Acta geologica polonica*. 52(2): 129-168.

White CA & Whitfield RP. 1862. Observations upon the rocks of the Mississippi Valley which have been referred to the Chemung group of New York, together with descriptions of new species of fossils from the same horizon at Burlington, Iowa. *Proceedings of the Boston Society of Natural History*. 8: 289–306.

Williams A, Brunton CHC, Carlson SJ, Alvarez F, Ansell AD, Baker PG, Bassett MG, Blodgett RB, Boucot AJ, Carter JL, Cocks LRM, Cohen BL, Copper P, Curry GB, Cusack M, Dagys AS, Emig CC, Gawthrop AB, Gourvenec R, Grant RE, Harper DAT, Holmer LE, Hong-Fei H, James MA, Yu-Gan J, Johnson JG, Laurie JR, Lazarev S, Lee DE, Lüter C, Mackay S, MacKinnon DI, Manceido MO, Mergl M, Owen EF, Peck LS, Popov LE, Racheboeuf PR, Rhodes MC, Richardson JR, Jia-Yu R, Rubel M, Savage NM, Smirnova TN, Dong-li S, Walton D, Wardlaw B, Wright AD. 2000. *Treatise on invertebrate paleontology*. Part H. Brachiopoda (Revised 2), Linguliformea, Craniiformea, and Rhynchonelliformea (part). Geological Society of America and University of Kansas Press. 2: 1-919.

Williams A, Brunton CHC, Carlson SJ, Alvarez F, Ansell AD, Baker PG, Bassett MG, Blodgett RB, Boucot AJ, Carter JL, Cocks LRM, Cohen BL, Copper P, Curry GB, Cusack M, Dagys AS, Emig CC, Gawthrop AB, Gourvenec R, Grant RE, Harper DAT, Holmer LE, Hong-Fei H, James MA, Yu-Gan J, Johnson JG, Laurie JR, Lazarev S, Lee DE, Lüter C, Mackay S, MacKinnon DI, Manceido MO, Mergl M, Owen EF, Peck LS, Popov LE, Racheboeuf PR, Rhodes MC, Richardson JR, Jia-Yu R, Rubel M, Savage NM, Smirnova TN, Dong-li S, Walton

D, Wardlaw B, Wright AD. 2007. Treatise on invertebrate paleontology. Part H. Brachiopoda (Revised) 6. Geological Society of America and University of Kansas Press. 2321-3226

Williams A, Brunton CHC, Carlson SJ, Holme RLE, Popov LE. 1996. A supra- ordinal classification of the Brachiopoda. Philosophical Transactions of the Royal Society of London, Series B. 351: 1171–1193.

Yugan J & Waterhouse JB. 1986. Carboniferous rocks and invertebrate faunas from Xizang Autonomous Republic (Tibet). The Indian Geologist Association. 19(2): 113-123.

Zhang Y, Lee S, Wu HT, He WH. 2018. Palaeobiogeographical distribution of Orbiculoidea (Brachiopoda, Discinoidea) responding to global climatic and geographical changes during the Palaeozoic. Paleontology. 61(2): 221-234. <https://doi.org/10.1111/pala.12339>

CAPÍTULO 7 RELATIONSHIPS BETWEEN BRACHIOPOD FAUNA (LOCHKOVIAN–FRASNIAN) FROM NORTHWEST GONDWANA (AMAZONAS BASIN) AND ENVIRONMENTAL CHANGES DURING THE DEVONIAN.

Luiz Felipe Aquino Corrêa ^{a*} and Maria Inês Feijó Ramos ^b

^a Geosciences Institute, Federal University of Pará, Rua Augusto Corrêa, 1 - Guamá, 66075-110, Belém-PA, Brazil.

^b Museu Paraense Emílio Goeldi, Coordination of Earth sciences, Avenida Perimetral, 1901 - Terra Firme, 66077-830, Belém-PA, Brazil.

Artigo publicado em **Palaeogeography, Palaeoclimatology, Palaeoecology** 629 (2023): 111803

Highlights

1. The variation of genera of brachiopods during the Devonian in the Amazonas Basin comprises three distinct stages.
2. The peak of brachiopod diversity occurred in the Eifelian, when the Amazonas Basin was between the subtropical latitudes 30°S and 60°S, under shallow marine conditions, and the global ocean temperature exceeded 22 °C.
3. The first diversity decline is recorded in the Ererê Formation, when there was a relative rise in sea level reaching deeper waters, and the ocean temperature had a slight cooling compared to the time deposition of the Maecuru Formation.
4. The fauna of the Barreirinha Formation records the second decline. The brachiopods from the Barreirinha Formation occur in layers of black shale with anoxic conditions and high stress attributed to an offshore environment.

ABSTRACT

The Devonian marked a significant phase in the evolutionary history of the Brachiopoda. During this period, the Phylum achieved its peak diversity (Emsian) and suffered one of its greatest declines (Frasnian–Famennian), ranking second only to the mass extinction event at the Late Permian period. In Brazil, the Amazonas Basin has a rich record of Devonian brachiopods distributed in four stratigraphic units: i) Manacapuru (Lochkovian), ii) Maecuru (early Eifelian), iii) Ererê (late Eifelian), and iv) Barreirinha (early Frasnian) formations. This article aims to survey the occurrences of brachiopods during the Devonian in the Amazonas

Basin and to discuss the possible factors that influenced their diversity. Environmental changes may explain the variation of brachiopod diversity throughout the Devonian in the Amazonas Basin. We noted that the diversity variation of Devonian brachiopods in the Amazonas Basin unfolded in three distinct stages. The peak of brachiopod diversity occurred in the early Eifelian (Maecuru Formation), when the Amazonas Basin was between the subtropical latitudes 30°S and 60°S, under shallow marine and cold conditions, justified by the absence of carbonates, evaporites, and reefs in the region (Stage 1). The first diversity decline is recorded in the Ererê Formation (late Eifelian), attributed to a warmer climate and deeper water than in the Maecuru Formation (Stage 2). During the Frasnian, there was a second diversity decline of brachiopods in the Amazonas Basin (Barreirinha Formation). A major global transgression occurred in the Late Devonian. In this period, the Amazonas basin experienced the deepest marine conditions in its history. The brachiopods of the Barreirinha Formation occur in layers of black shale (offshore), attributed to an anoxic or dysoxic environment of high stress, which explains the low diversity of brachiopods in this unit (Stage 3).

Keywords: North of Brazil; Invertebrate marine; Paleozoic; Sea level.

7.1 INTRODUCTION

Brachiopods have a complete fossil record, emerging in the Cambrian period and occurring in smaller proportions in modern oceans (Williams *et al.* 2007, Harper *et al.* 2017). The apex of their diversity was in the Devonian, with a record of 460 genera during the Emsian. In the same period occurred the second largest faunal decline during the Famennian, with the most significant decline during Permo–Triassic extinction (Williams *et al.* 2007).

During the Silurian–Devonian transition, with the melting of the polar ice caps that covered part of Africa and South America resulted in marine transgressions that reached a large part of the supercontinent Gondwana. It was in this context that the shallow seas in Northwest Gondwana appeared in the Early Devonian (Carozzi *et al.* 1973, Caputo 1984, Johnson 2006, Torsvik & Cocks 2013). The emergence of these seas was one of the main factors for the Phylum to reach the peak of its diversity during this period.

In Brazil, the Amazonas Basin has a rich record of Devonian brachiopods distributed in four formations (Figure 39): i) Manacapuru Formation (Lochkovian), ii) Maecuru Formation (early Eifelian), iii) Ererê Formation (late Eifelian), and iv) Barreirinha Formation (early Frasnian) (Rathbun 1874, Clarke 1913, Fonseca & Ponciano 2011, Corrêa & Ramos 2021). Most of these records are from samples of the Maecuru and Ererê formations, coming from

expeditions that took place in the 19th century (Morgan Expeditions between 1870-1871, and Imperial Geological Commission of Brazil between 1875-1877) and 20th century (Geological and Mineralogical Service of Brazil in between 1918-1929, and Expedition Orville Adalbert Derby in 1986).

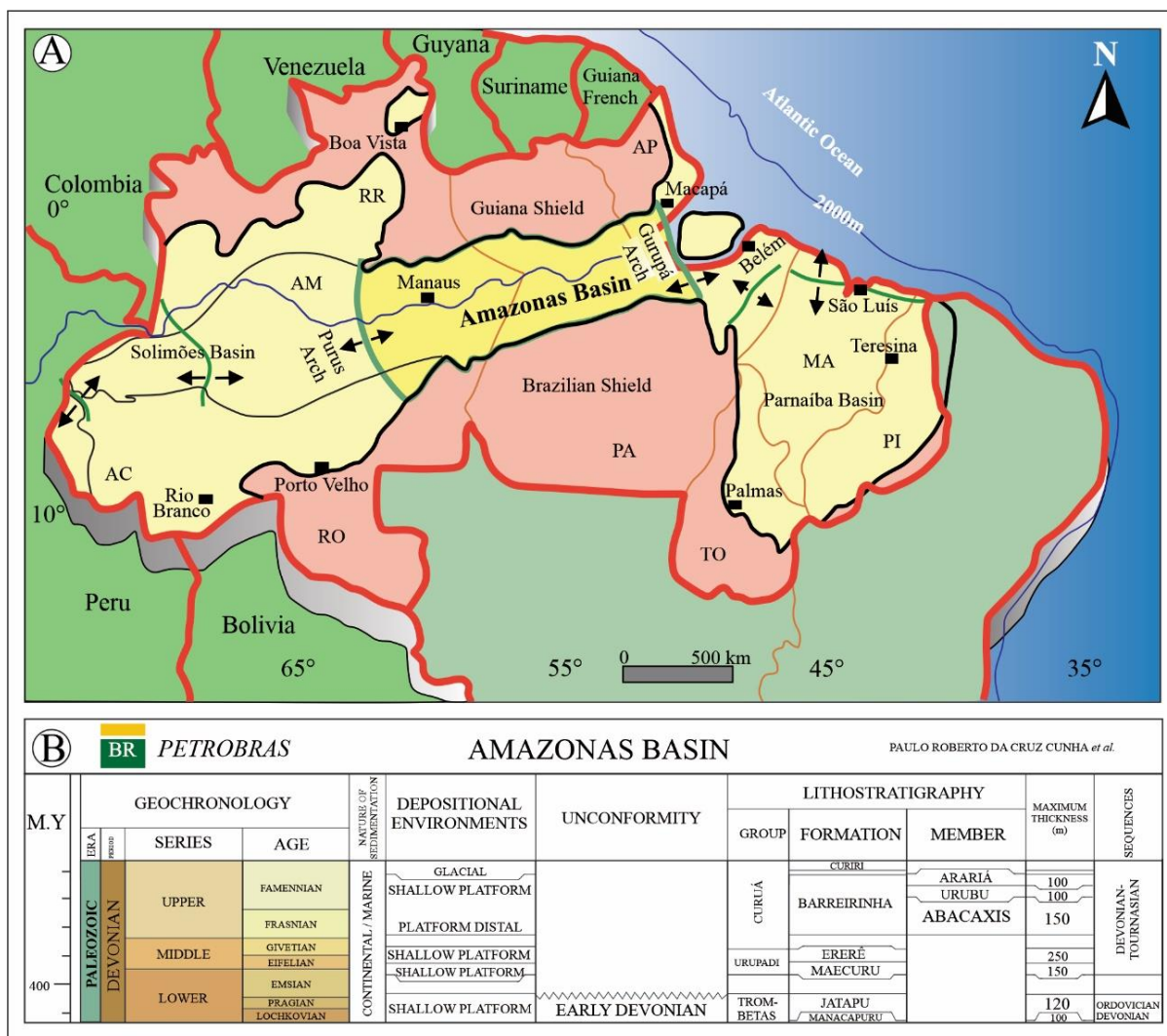


Figure 39- A) Location of the Amazonas Basin (Cunha 2000); B) Stratigraphic chart of the Amazonas Basin (Cunha *et al.* 2007), highlighting the Devonian.

Recently, paleontological studies in the Manacapuru Formation have advanced due to the rescue of more than 3,000 fossil samples, of which 1,386 were brachiopods, collected during the Program of paleontological salvage at Belo Monte hydroelectric power plant construction in the municipality of Vitória do Xingu, Pará State (Tomassi *et al.* 2015). Corrêa & Ramos (2021) studied part of this material and identified three species of the family Discinidae from the Manacapuru Formation (Amazonas Basin): *Orbiculoidea baini*, *Orbiculoidea bodenbenderi*, and *Orbiculoidea excentrica*. The authors also proposed two new species, *Orbiculoidea katzeri*, and *Orbiculoidea xinguensis*.

Approximately 150 years have passed since the first publication on the Devonian brachiopods of the Amazonas Basin. Much of the research is concentrated on samples from the Eifelian, which mainly addresses the paleobiogeographical and taxonomic aspects of brachiopods, and a good part of these identifications need to be revised (Derby 1877, Rathbun 1874, 1878, Katzer 1897, Clarke 1899, Katzer 1903, Clarke 1913, Katzer 1933, Carvalho 1972, 1975, Melo 1985, Fonseca 2004, Fonseca & Ponciano 2011). Besides, in these studies, the authors do not discuss the factors that influenced the variation in the diversity of genera and species of brachiopods along the Devonian in the Amazonas Basin.

Since the first paleobiogeographical studies of the Devonian, the affinities between brachiopod species found in the Amazonas Basin and those in other regions have been observed and discussed. Clarke (1913) pointed out that the invertebrate fauna of the Ererê Formation had a boreal affinity, similar to the forms that occurred further north in the Devonian. For Boucot *et al.* (1969) and Boucot (1971), the invertebrate fauna of the Maecuru and Ererê formations belonged to the Eastern Americas Realm, characterized by temperate waters, and located between the Old World and Malvinokaffric realms (now called Malvinohosan Realm by Penn-Clarke & Harper 2020), in the middle to low latitudes (30°S–60°S). Recently, Penn-Clarke & Harper (2020) proposed a new bioregionalization for West Gondwana during the Pragian–Eifelian interval based on the distribution of brachiopods. According to the authors, the Amazonas Basin was in a border region between two first-order biogeographical units: “Temperate (30°S–60°S) latitude” and “High (60°S–90°S) latitude” (Penn-Clarke & Harper 2020).

This article aims to survey of occurrences of brachiopods during the Devonian in the Amazonas Basin and to discuss the factors possibly that influenced their diversity. We adopted the taxonomic classification described by Carvalho (1975), Melo (1985), and Fonseca (2004).

7.2 DATA AND METHODS

A database on Devonian brachiopods from the Amazonas Basin was generated from the literature records. Additionally, we consulted online paleontological collections and the curators of the following institutions:

NMNH, National Museum of Natural History of the Smithsonian Institution.

NYSM, New York State Museum, Albany.

MN/UFRJ, Museu Nacional, Universidade Federal do Rio de Janeiro.

MPEG, Museu Paraense Emílio Goeldi.

MCT/DNPM, Museu de Ciências da Terra do Departamento Nacional de Produção Mineral.

The data were organized in an Excel program (see Supplemental Material Table S1) containing the following information: catalog number, taxon, geographic and geological location, collectors, and observations. For the taxonomic information, we followed the information provided by the literature and the curators of each collection. Therefore, we did not conduct a taxonomic review of this material since it is not the objective of this study.

7.3 MAJOR SCIENTIFIC EXPEDITIONS IN THE DEVONIAN OF THE AMAZONAS BASIN

Brachiopod research in the Amazonas Basin (Figure 40) started in the 19th century, with the Morgan Expeditions (1870 and 1871), led by Charles Frederick Hartt, in the Ererê region (Katzer 1933). In 1875, Dom Pedro II authorized the creation of the Geological Commission of Brazil (Katzer 1933). The scientists of that commission visited the Serra de Ererê and discovered new outcrops rich in fossils on the banks of the Maecuru and Curuá rivers, also explored by Katzer in 1897 (Katzer 1933, Fonseca & Ponciano 2011). Later, João Coelho (March 1895), carried out an expedition through the Maecuru River and collected invertebrate fossils in sandstone at the Teuapixuna waterfall (Katzer 1897, Moura 1938, Fernandes & Scheffler 2014).

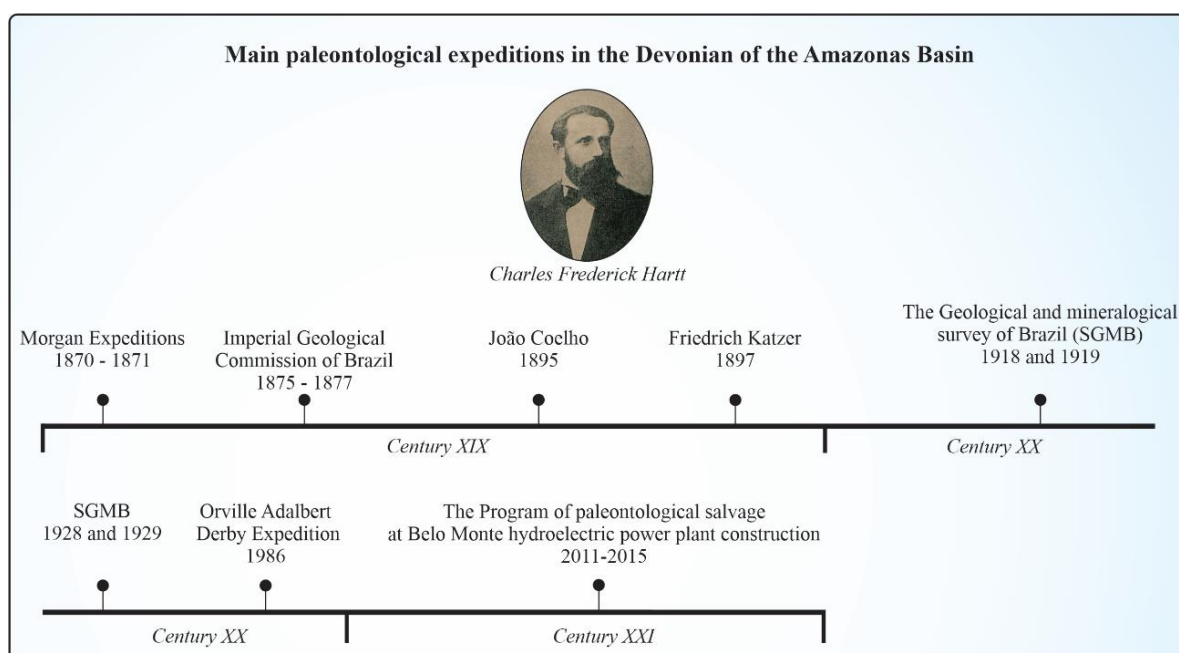


Figure 40- Expeditions in the Amazonas basin.

During the 20th century, there were expeditions by the Geological and Mineralogical Survey of Brazil and the Orville Adalbert Derby Expedition. In 1918, technicians from the Geological and Mineralogical Service of Brazil conducted an expedition in the Amazonas Basin, where they collected fossils of Devonian brachiopods on the banks of the Urubú River, close to the municipality of Iracema, in the state of Amazonas. One year later, the same team found brachiopod fossils at rivers Erepecuru and Curuá banks (Albuquerque 1922). In 1928, Anibal Alves Bastos and Pedro de Moura collected invertebrate fossils upstream of the Tenapizuruna Waterfall on the Maecuru River, State of Pará (Bastos & Moura 1929). In the following year, Mathias G. de O. Roxo and José Moreira Mendonça collected brachiopods in outcrops close to Serra de Ererê and from a core in Serra de Itauajuri (Oliveira 1930).

Fifty years later, scientific expeditions in the Devonian of the Amazonas Basin returned with the Orville Adalbert Derby Expedition (1986), headed by José Henrique Gonçalves de Melo. This expedition explored the classic outcrops of the Serra de Ererê and the banks of the Maecuru River in the Amazonas Basin, carried out an expressive fossiliferous collection and the first geographic records of these locations (Figure 29 A and B) (Fonseca & Ponciano 2011, Fernandes & Scheffler 2014). After 35 years of the Orville Adalbert Derby Expedition, a new expressive collect occurred during the Program of paleontological salvage of the Belo Monte hydroelectric power plant construction in the Vitória do Xingu, Pará State, between the years 2011 and 2015 (Figure 29 C and D), Tomassi *et al.* (2015) collected approximately 1386 samples of brachiopods from the Manacapuru Formation.

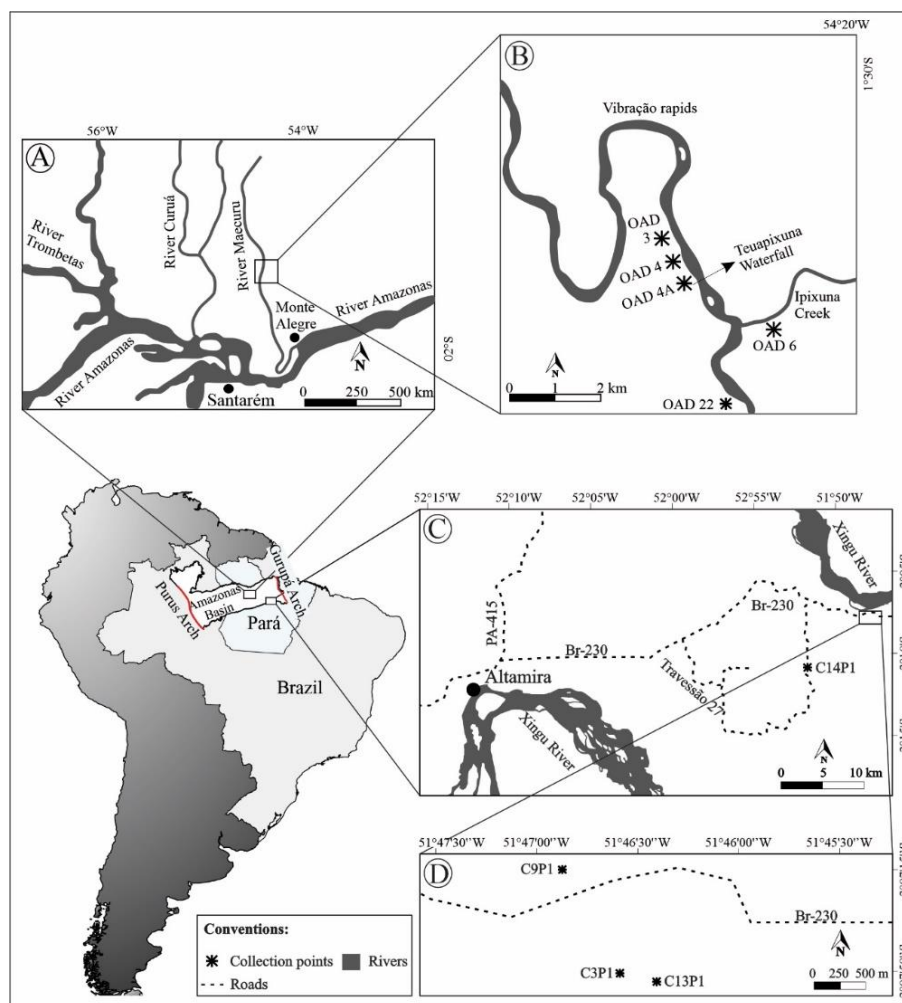


Figure 41- A) and B) Sampling sites of the Maecuru (OAD3, OAD4, and OAD4A) and Ererê (OAD6 and OAD22) formations marked during the Orville Adalbert Derby Expedition (Fonseca 2004). C) and D) Sampling sites of the Manacapuru Formation (Corrêa & Ramos 2021).

7.4 DEVONIAN BRACHIOPODS FROM THE AMAZONAS BASIN DEPOSITED IN MUSEUMS AND UNIVERSITIES

Six institutions store the brachiopod samples collected over the last 150 years in the Amazonas Basin: two in the United States of America (the NMNH and NYSM) and four in Brazil (MN/UFRJ, MPEG, MCT/DNPM, and the Laboratório de Estudos de Comunidades Paleozóicas at the Federal University of the State of Rio de Janeiro) (see **Supplemental Material Table S1**).

Most of the collected material from the Morgan Expeditions is at the NMNH (Rathbun 1878). The type and figured specimens published by Katzer (1897, 1903, 1933) are currently deposited at the NYSM, as reported by Fonseca & Ponciano (2011) and Fernandes & Scheffler (2014).

The MN/UFRJ stores part of the samples collected by the Imperial Geological Commission of Brazil and the Orville Albert Derby Expedition, in addition to the type

specimens of brachiopods collected during the Morgan Expeditions, transferred from the NMNH (Fonseca & Ponciano 2011). The collection of paleoinvertebrates at the MN/UFRJ stored 657 samples of Devonian fossils from the Amazonas Basin before the fire in the museum on September 2nd, 2018 (Fernandes & Scheffler 2014). During the recovery work after the accident, Dr. Sandro Marcelo Scheffler managed to rescue two samples of brachiopods, one bivalve, and one cephalopod collected by the Imperial Geological Commission of Brazil (Silva *et al.* 2019).

In the Paleontological collection from the MPEG, 64 specimens collected by João Coelho, coming from the Maecuru Formation, 17 samples collected by Friederich Katzer from the Ererê Formation, and 1386 fossils samples of brachiopods collected by Henrique Tomassi (Figure 42), from the Manacapuru Formation are stored.

The paleoinvertebrate collection of the MCT/DNPM is composed of samples collected by the Imperial Geological Commission of Brazil, the Geological and Mineralogical Survey of Brazil, and the Orville Albert Derby expeditions. It includes 313 specimens of brachiopods from the Maecuru Formation and 47 from the Ererê Formation. Part of the fossil material from the Orville Albert Derby expedition is at the Laboratório de Estudos de Comunidades Paleozoicas at the Federal University of the State of Rio de Janeiro (Fonseca & Ponciano 2011, Fernandes & Scheffler 2014).

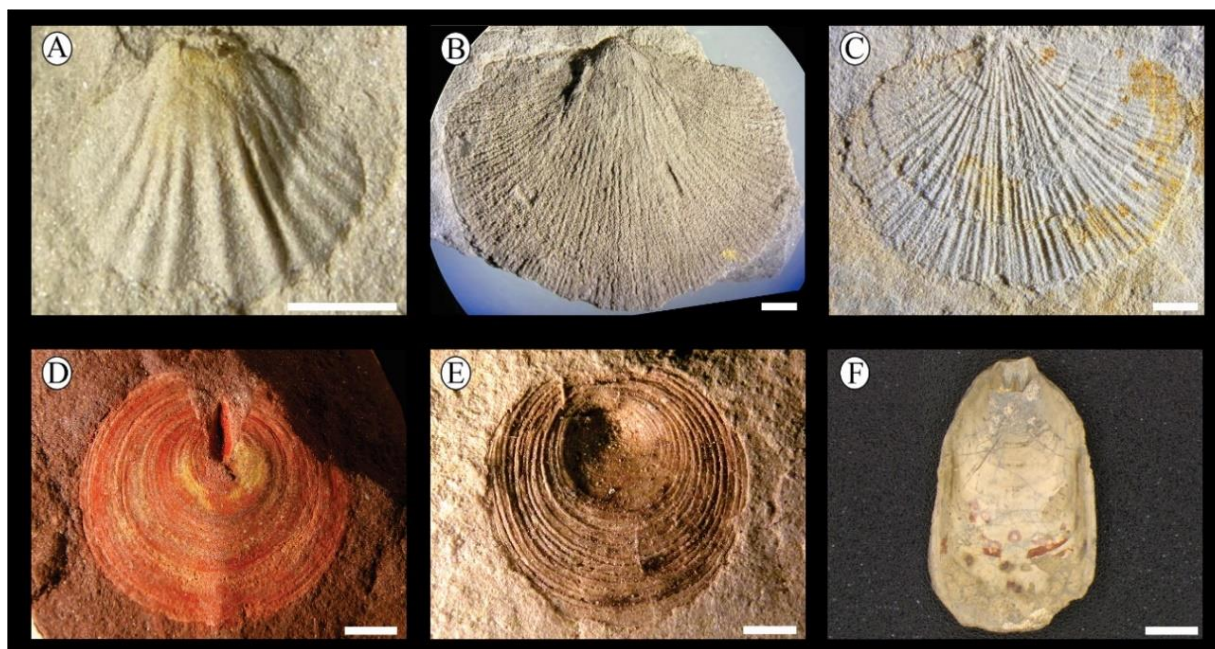


Figure 42- Brachiopods collected during the Program of paleontological salvage of the Belo Monte hydroelectric power plant construction and stored in the paleontological collection from Museu Paraense Emílio Goeldi. Rhynchonellata: A) MPEG-4155-I, B) MPEG-4156-I and C) MPEG-4157-I; Lingulata: D) MPEG-3660-I, E) MPEG-3686-I and F) MPEG-4154-I. Scale bar: 2mm. Source: A) – C) and F) author; D) – E) Corrêa & Ramos (2021).

7.5 THE DEVONIAN BRACHIOPODS FROM THE AMAZONAS BASIN

The Devonian strata in the Amazonas Basin document the presence of three classes, nine orders, 31 genera, and 52 species of brachiopods distributed among the Manacapuru, Maecuru, Ererê, and Barreirinha formations (see **Supplemental Material Table S2**). The Jatapu and Curiri formations do not have any records of Devonian brachiopods.

7.5.1 Manacapuru Formation (Lochkovian)

Grahn & Melo (1990) were the first authors to report the occurrence of brachiopods in layers of the Manacapuru Formation (*Lingula* sp.) from the Amazonas Basin, but without providing any taxonomic or taphonomic details. Later, Tomassi *et al.* (2015) made a preliminary report on the fossiliferous material recovered during the Program of paleontological salvage of the Belo Monte hydroelectric power plant construction. The authors have drawn attention to the large number of Rhynchonellata and Lingulata brachiopods collected from layers corresponding to the upper portion of the Manacapuru Formation, highlighting the need for further taxonomic studies of this material.

The first taxonomic study on brachiopods from the Manacapuru Formation collected in Belo Monte was published by Corrêa & Ramos (2021), focusing on the taxonomic identification of inarticulate brachiopods from the Discinidae Family. The authors recorded the first occurrence of *Orbiculoidea baini*, *Orbiculoidea bodenbenderi*, and *Orbiculoidea excentrica* in the Amazonas Basin and described two new species (*Orbiculoidea xinguensis* and *Orbiculoidea katzeri*). The records of *Orbiculoidea baini*, *Orbiculoidea bodenbenderi*, and *Orbiculoidea excentrica* in the layers of the Manacapuru Formation (Lochkovian) are the oldest in South America. The authors believe that these *Orbiculoidea* occurrences in the Manacapuru Formation may be related to the proximity of the Amazonas Basin (located in northwest Gondwana) with the Laurasia paleocontinent (which concentrated the highest occurrences of brachiopods during the Silurian–Devonian) during the Early Devonian. Another factor was the global sea-level rise during this period, which flooded part of northwest Gondwana, resulting in shallow marine conditions in the Amazonas Basin and consequently expanding ecological niches of marine fauna.

7.5.2 Maecuru Formation (early Eifelian)

In 1876, Orville Adalbert Derby made the first record of brachiopods from the Maecuru Formation in a sandstone layer from the banks of the Maecuru and Curuá rivers (Derby 1877). Rathbun (1878) conducted further taxonomic studies on this material and identified 21 species,

eight of which were new. Subsequently, several researchers, such as Katzer (1897, 1903, 1933), Clarke (1899, 1913), Carvalho (1975), Melo (1985), and Fonseca (2004), revised and studied part of the taxa identified by Rathbun, along with additional material acquired in the following decades.

Carvalho (1975) reviewed the brachiopods of the Orthida, Strophomenida, Spiriferida, and Terebratulida orders from the Maecuru Formation, first studied by Rathbun (1878) and Katzer (1897, 1899, 1903). In his work, of the 11 species identified, only *Tropidoleptus carinatus* and *Amphigenia elongata* remained with their original classification. The other nine species were reclassified as *Discomyorthis hatti*, *Platyorthis nettoana*, *Protoleptostrophia* sp., *Megastrophia hoeferi*, *Acrospirifer duodenaria*, *Acrospirifer buarquiana*, *Mucrospirifer pedroanus*, *Plicoplasia curupira*, *Derbyina jamesiana*, and *Paranaia wardiana*.

Fonseca (2004) studied the superfamily Chonetoidea from the Maecuru and Ererê formations. The author established the diagnosis of *Chonetes freitasi* Rathbun, 1878, designating its lectotypes and paralectotypes, besides proposing a new species: *Montsenetes carolinae*.

The following taxa listed herein have questionable identifications and require revision: *Podolella rathbuni*, *Mucrospirifer katzeri*, *Australospirifer? laurosodreanus*, *Spirifer derbyi*, *Spirifer hartti*, *Cyrtina? maecuruensis*, *Camarotoechia? aff. C. soppho*, *Leptocoelia? sp.*, *Chonetes? curuaensis*, *Productella maecuruensis*, *Anoplia nucleata*, *Chonostrophia knodi* and *Schuchertella agassizi*. The complete list of brachiopods from the Maecuru Formation is in **supplemental material table S2**.

The paleoecological data inferred for the Maecuru Formation come from studies of two associations of benthic marine invertebrates: *Schuchertella agassizi* – *Ptychopteria eschwegei* and *Mucrospirifer katzeri* – *Ptychopteria eschwegei* (Ponciano *et al.* 2007a, 2007b). The first is the only one to have brachiopods, represented by 12 species, which correspond to 44% of the individuals in the association, followed by 20 species of bivalves, 12 of trilobites, 14 of gastropods, 3 of crinoids, and 3 of tentaculites. The semi-quantitative and morpho-functional analyses indicated a shallow marine paleoenvironment with agitated waters, well-oxygenated, temperate, and normal salinity (Ponciano *et al.* 2007a).

The material sampled by the Morgan Expeditions, the Imperial Geological Commission of Brazil, and the Orville A. Derby Expedition did not follow standard collection models for taphonomic analysis, which may result in misinterpretations, which makes it unfeasible and justifies the absence of taphonomic studies.

The brachiopods from the Maecuru Formation occur in the upper portion of the unit, dated through myospores and chitinozoans as early Eifelian (Melo & Loboziak 2003, Grahn & Melo 2004, Fonseca & Ponciano 2011).

During the Middle Devonian, the Amazonas Basin was in a paleobiogeographic frontier region, which probably explains the mixture of faunal elements from the Old World, Eastern Americas, and Malvinohosan realms (Melo 1985, Fonseca & Ponciano 2011). Among the brachiopods, there is a predominance of the genera with affinities to the Eastern Americas realm (11 genera), as well as elements from the Old World (8 genera) and Malvinohosan (4 genera) realms. The brachiopods of the Maecuru Formation are part of the Amazon-Colombian subprovince (Boucot 1975, Boucot *et al.* 2001).

Recently, Penn-Clarke & Harper (2020) proposed a new bioregionalization for West Gondwana during the Pragian–Eifelian interval based on the distribution of brachiopods (Figure 43). The authors identified two first-order areas: the “Temperate Latitude” and “High Latitude” bioregions. The High Latitude bioregion comprises two second-order regions: the “Amazonian” and “Malvinohosan” regions (Penn-Clarke & Harper 2020). The Maecuru and Ererê formations are inserted in the Amazonian unit, restricted to latitudes 50°S–60°S, situated in a region intermediate between the Colombian–West African and Malvinohosan bioregions.

7.5.3 Ererê Formation (late Eifelian)

The brachiopods from the Ererê Formation occur in layers dated to the late Eifelian age (Melo & Loboziak 2003, Grahn & Melo 2004, Fonseca & Ponciano 2011). Carvalho (1975), Melo (1985) and Fonseca (2004) revised most of the taxa from the Ererê Formation. Carvalho (1975) reclassified six species (*Platyorthis nettoana*, *Derbyina jamesiana*, *Paranaia wardiana*, *Podolella derbyana*, *Mucrospirifer pedroanus*, and *Plicoplasia curupira*) that Rathbun (1874) had previously proposed, and only *Tropidoleptus carinatus* maintained its original classification.

The brachiopods of the Chonetidae Family from the Ererê Formation show inconsistencies in their taxonomic classification due to the poor preservation of important diagnostic characteristics. Rathbun (1874) made the first record of this family, which was later revised by Clarke (1899), Katzer (1933), Kegel (1953), and Melo (1985), who did not reach a consensus regarding the classification. Fonseca (2004) reviewed the *Chonetes* from the Ererê Formation and reclassified *Chonetes comstockii* as *Pleurochonetes comstocki*. The species that Rathbun (1874) classified as *Chonetes freitasi*, *Chonetes herbertsmithi*, and *Chonetes onettianus* do not present a good state of preservation, which does not allow for a detailed

description of the material, putting even their classification at the genus level in doubt (Fonseca & Ponciano 2011).

Considering this taxonomic review, the brachiopod fauna of the Ererê Formation includes *Schuchertella agassizi*, *Camarotoechia?* aff. *C. dotis*, *Rhynchonella ererensis*, *Orbiculoidea* sp., *Lingula ererensis*, and *Lingula spatulata*.

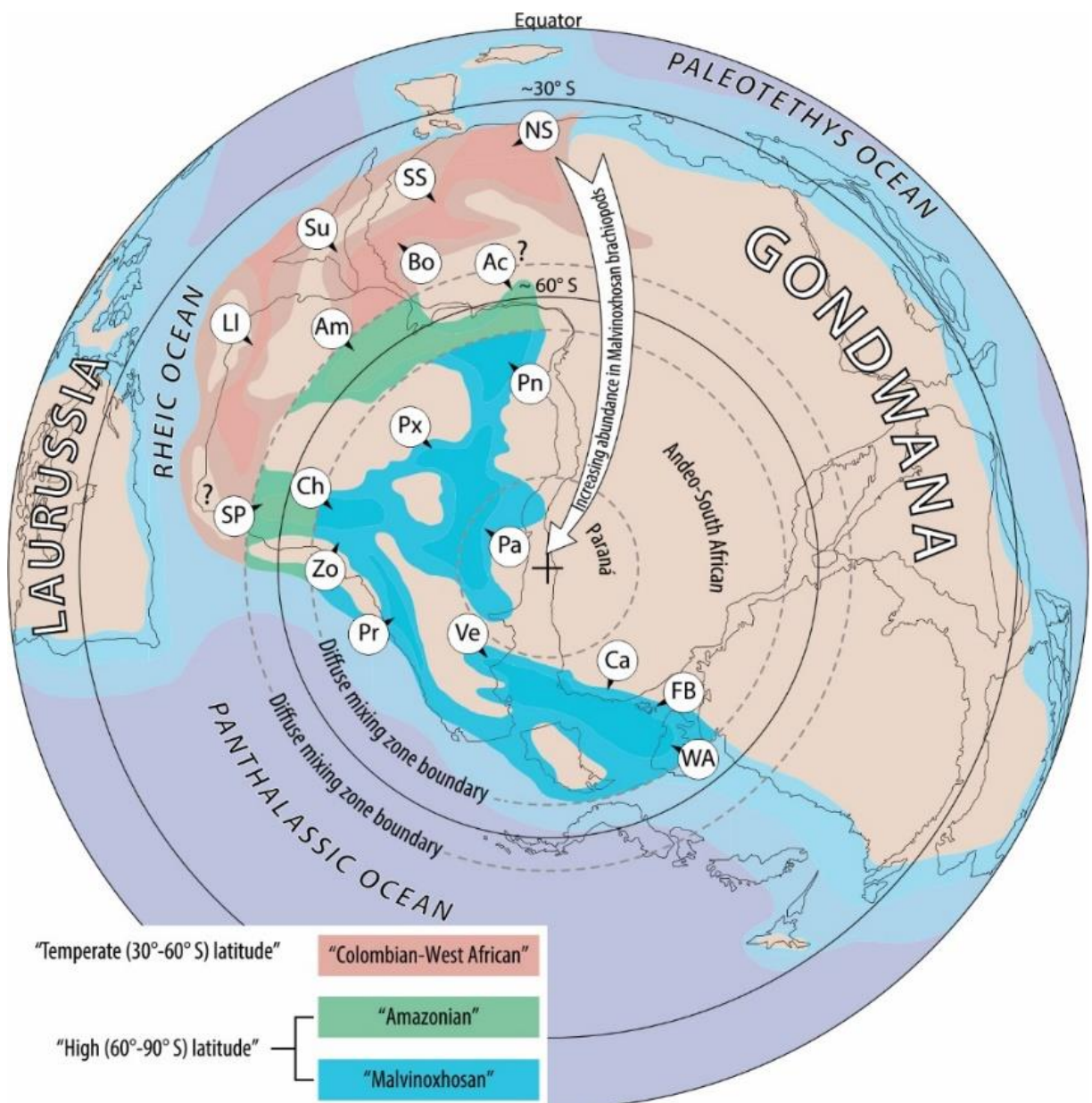


Figure 43- Brachiopod-based bioregions of West Gondwana during the Pragian–Eifelian (Penn-Clarke & Harper 2020). Abbreviations: Ac—Accraian (Ghana), Am—Amazonas (Brazil), Bo—Bové (Guinea, Guinea-Bissau, Senegal), Ca—Cape (South Africa), Ch—Chaco (Bolivia), FB—Fox Bay (Falkland Islands), LI—Llanos (Colombia and Venezuela), NS—“North Saharan” (Tindouf, Ghadamis, Polignac, Murzuq basins), Pa—Paraná (Brazil, Paraguay, Uruguay), Px—Parecis (Brazil), Pr—Precordillera (western Argentina), Pn—Parnaíba (Brazil), SP—southern Peru, SS—“South Saharan” (Tamesna and Taoudeni basins and Adrar, Hodh regions), Su—Suwannee (Florida, Georgia, United States), Ve—Ventana (eastern Argentina), WA—West Antarctica (“Ellsworth-Whitmore Mountains”), Zo—Zorritas (northern Chile).

7.5.4 Barreirinha Formation (early Frasnian)

The brachiopods of the Barreirinha Formation occur in a layer of black shale dated as early Frasnian (Melo 1985, Melo & Laboziak 2003). Rathbun (1874) described the species *Lingula gracana*, *Lingula stauntoniana*, *Lingula rodriguezii*, *Orbiculoidea lodensis*, and *Vitulina pustulosa* from black shale layers of the Barreirinha Formation and observed that the fauna of the Ererê region is similar to the fauna recorded in the Hamilton Group from New York.

Dr. Israel Charles White, head of the Coal Commission, provided material collected from the black shale of the Ererê region to Clarke (1913), who analyzed it and identified *Schizobolus truncatus*. This author was one of the pioneers to consider the possibility of this layer being the first record of the Upper Devonian in South America. Later, Macambira *et al.* (1977) mentioned the occurrence of *Orthotetes agassizi* and *Spirifer* sp. in a black shale layer attributed to the old Barreirinha Member in the Altamira region, Pará State. The fauna of the Barreirinha Formation has no element of the Devonian paleobiogeographic province or domain.

7. 6 RESULTS AND DISCUSSIONS

Unlike the Devonian, there is no record of brachiopods during the Ordovician in the Amazonas Basin. For the Silurian, only Clarke (1899) registered a brachiopod fauna collected on the banks of the Trombetas River, referring to the lower portion of the Pitinga Formation, dated through biostratigraphic analysis with chitinozoans as Llandovery – early Wenlock (Grahn 2005).

We observed that the variation in diversity of Devonian brachiopods in the Amazonas Basin occurred in three distinct stages (Figure 44 A). In Stage 1, there was an increase in classes and genera of brachiopods during the Lochkovian–early Eifelian. The number of genera increased from one to twenty-five, representing the peak of brachiopod diversity during the Devonian in the Amazonas Basin.

In stage 2, the Amazonas Basin experienced its first decline in brachiopod diversity. Approximately 50% of the brachiopod genera went extinct between the early–late Eifelian. Subsequently, a second decline occurred between the late Eifelian–early Frasnian, characterizing stage 3. Additionally, it is possible to observe that the distribution of brachiopods in the Devonian of the Amazonas Basin, recorded until now, follows the global trend evolution of the Phylum during this period (Figure 44 B).

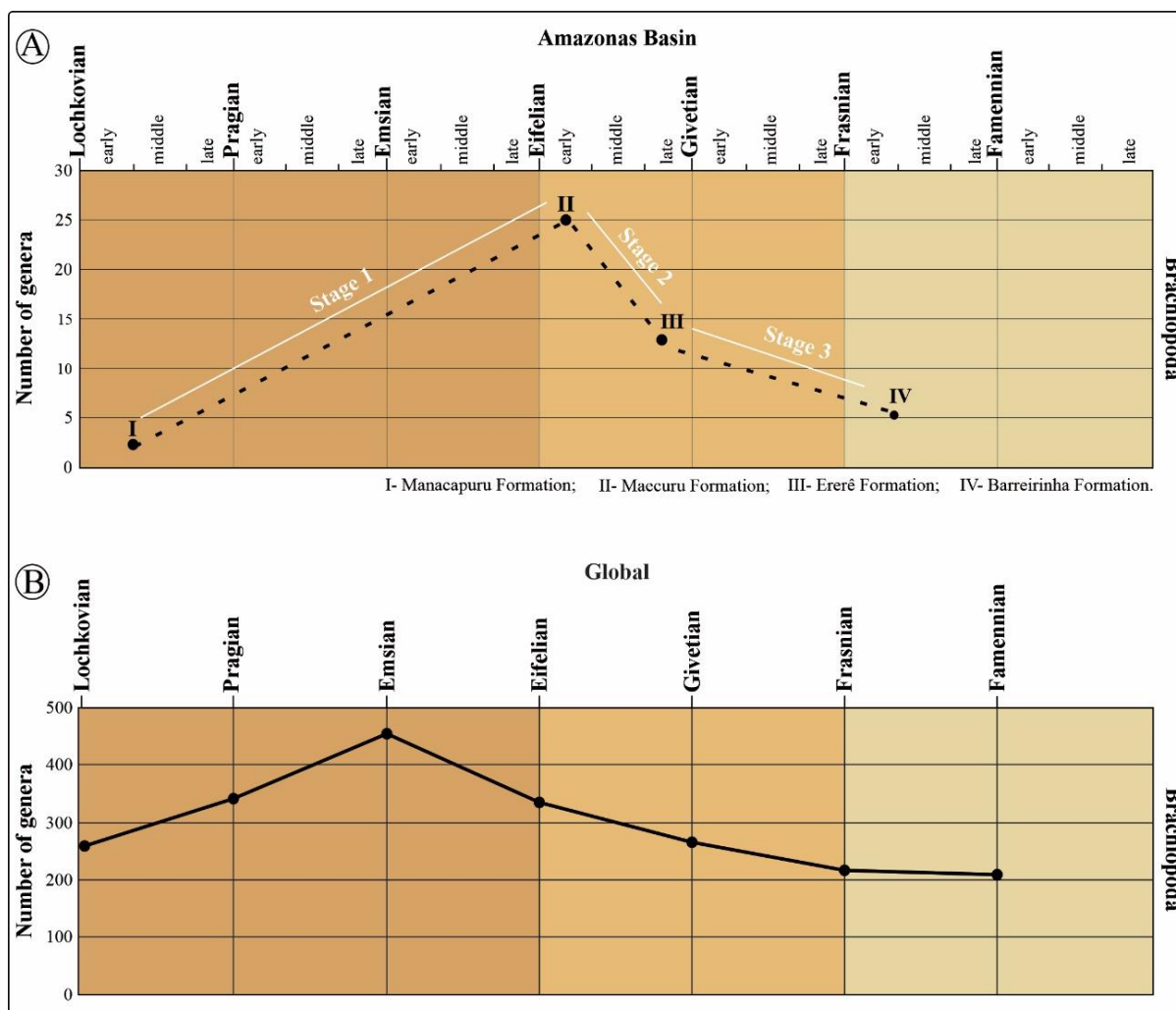


Figure 44- A) Distribution of the number of brachiopod genera in the Devonian of the Amazonas Basin. B) Global distribution of the number of brachiopod genera in the Devonian (Williams *et al.* 2007).

During the Ordovician (Figure 45) and Silurian, northwest of Gondwana was located at high latitudes (between 60°S–90°S) (Torsvik & Cocks 2013). In the Ordovician–Silurian transition, the Hirnantian glaciation occurred, lasting approximately 35 million years (Finnegan *et al.* 2011). Climatic conditions were extreme in northwest Gondwana when only a low diversity fauna composed of brachiopods Rhynchonelliformea and Linguliformea from the Iapó and Vila Maria formations (Paraná Basin) is recorded in Brazil (Zabini *et al.* 2019, 2021).

Brachiopods had a preference for areas of low latitude (15°N and 35°S) with relatively warm to temperate conditions during the Ordovician and Silurian periods, as seen in the case of brachiopods of the genus *Orbiculoidea*, which occurred only in the following locations during the Ordovician–Silurian: west of Laurentia (North America), Baltica (Germany) and the east bank of Gondwana (China) (Torsvik & Cocks 2013, Zhang *et al.* 2018).

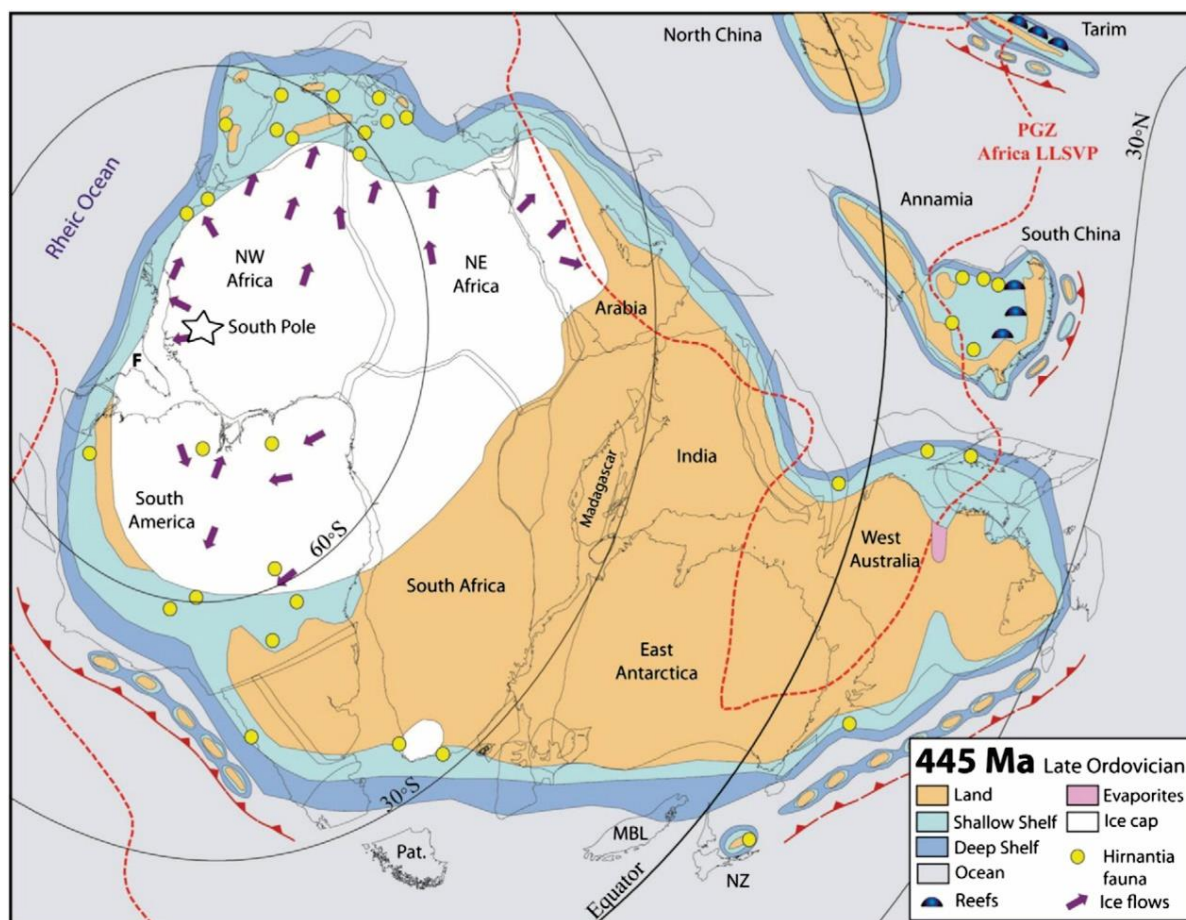


Figure 45- Paleobiogeographic arrangement of Gondwana 445 Ma. (Torsvik & Cocks 2013).

In the Silurian, parts of the North African and South American polar ice caps melted, raising the sea level and consequently causing marine transgressions that extended to several cratonic areas in the Gondwana (Caputo 1984, Torsvik & Cocks 2013). As a result, shallow seas emerged in the northwest of Gondwana during the Early Devonian, leading to the expansion of new ecological niches that contributed to the proliferation of brachiopods during the Devonian (Ludwig 1964, Caputo 1984, Caputo & Crowell 1985, Grahn & Caputo 1992, Cunha *et al.* 1994).

Environmental changes and the geographic position of paleocontinents may explain the variation in brachiopod diversity throughout the Devonian in the Amazonas Basin, as discussed below.

Stage 1: After a low sea level near the Silurian–Devonian boundary, global eustatic sea levels increased considerably in the Early Devonian (Figure 46 A) (Torsvik & Cocks 2016). Geographically, the Amazonas Basin was between the latitudes of 30°S and 60°S, the Gondwana was closer to Laurussia (Figure 48 A), and the global temperature of the oceans

increased (Figure 46 B) (Wallmann 2004, Torsvik & Cocks 2013). In this context, the brachiopods of the Manacapuru Formation emerged (Corrêa & Ramos 2021).

Among the Brazilian sedimentary basins, the Amazonas Basin is the only one to have brachiopod occurrences in the Lochkovian. This suggests a possible relationship with favorable environmental conditions since it is the only basin with a depositional environment related to a shallow marine platform. Another relevant factor is associated with the position of the paleocontinents. The Amazonas Basin was closer to Laurussia compared with the other Brazilian basins. Besides, the same transgression that enabled the emergence of a sea in the Amazonas Basin in the Lochkovian may have transported the cosmopolitan larvae of the *Orbiculoidea* brachiopods to this basin (Corrêa & Ramos 2021).

During the Early Devonian (Lochkovian), there was a predominance of brachiopods belonging to the Lingulata class, represented by the genus *Orbiculoidea* and other Linguliformes, in rocks of the Manacapuru Formation (Grahn & Melo 1990, Corrêa & Ramos 2021). Subsequently, at the early Eifelian, there was a significant increase in Rhynchonellata and Strophomenata found in strata of the Maecuru Formation (Figure 47).

In the Early Devonian, there was a clear differentiation between equatorial and polar temperatures, which led to a notable increase in the provinciality of shallow marine benthic faunas (Boucot & Blodgett 2001, Penn-Clarke & Harper 2020). Paleobiogeographic provinces peaked in the Emsian, the same age at which brachiopods reached maximum stratigraphic diversity at the genus level (Williams *et al.* 2007).

During the Eifelian (Figure 48 B), the climatic conditions in the Amazonas Basin were still cold, justified by the absence of carbonates, evaporites, and reefs in the region (Caputo 1984). In the Amazonas Basin, the brachiopods had the apex of their diversity with twenty-five genera and twenty-eight species, occurring in shallow marine conditions (Caputo 1984).

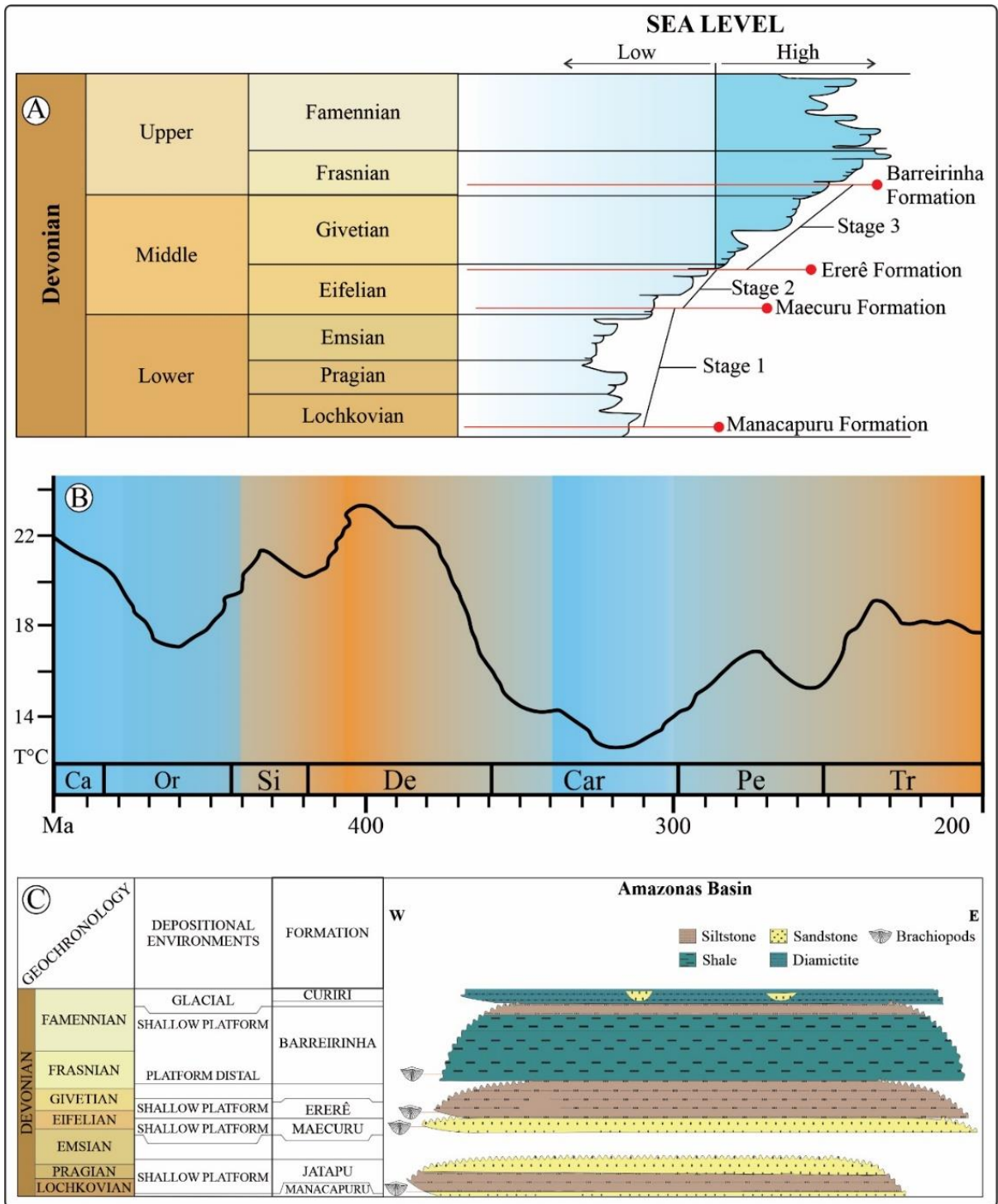


Figure 46- A) Global eustatic sea level variation in the Devonian (Ross & Ross 1988); B) global ocean average temperature from 500 to 200 Ma. (Wallmann 2004); C) Stratigraphy of the Devonian period in the Amazonas Basin (Cunha *et al.* 2007).

In addition to the great diversity of Rhynchonellata and Strophomenata, the Maecuru Formation is the only studied unit that does not show the occurrence of Lingulata (Figure 47). The absence of this class may be related to environmental factors. In the Manacapuru, Ererê, and Barreirinha formations, the Lingulatas are found in layers of siltstones, fine sandstones, and shales, respectively, associated with more distal environments (Caputo 1984, Melo 1985,

Fonseca & Ponciano 2011). On the other hand, the brachiopods of the Maecuru Formation occur in layers of fine to coarse sandstone, attributed to more proximal environments (Caputo 1984, Melo 1985, Fonseca & Ponciano 2011).

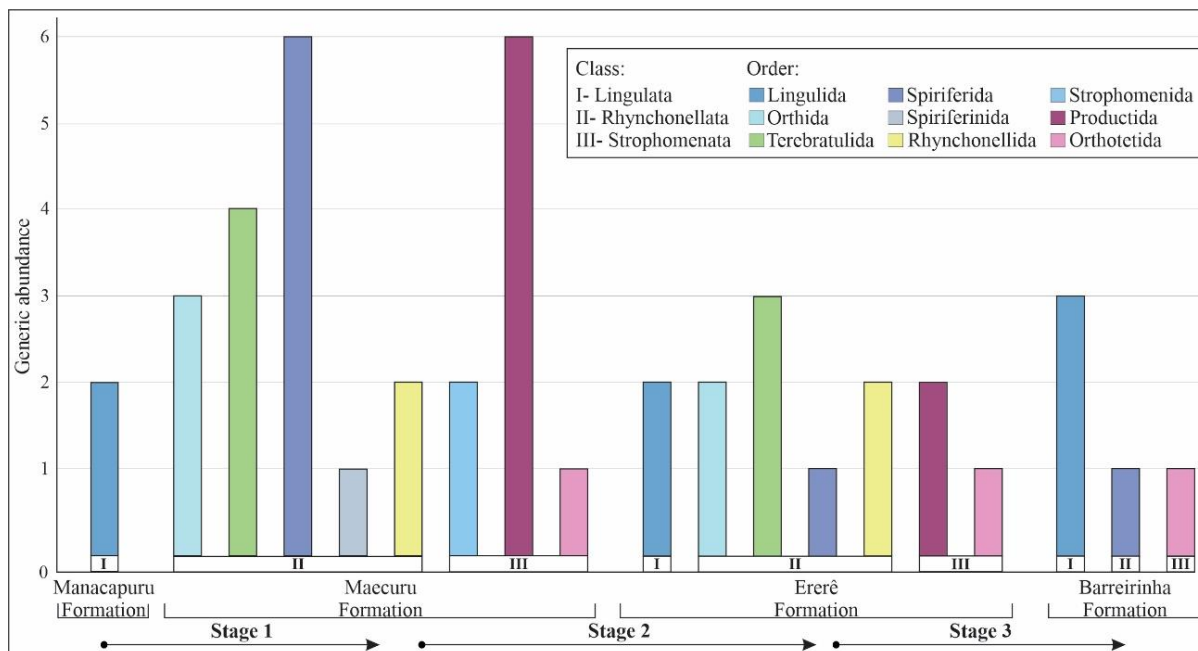


Figure 47- Brachiopod diversity (class, order, and genus) recorded in the Devonian units from the Amazonas Basin.

Stage 2: Thirteen genera and sixteen species of brachiopods occurred in offshore deposits of the Ererê Formation (Figure 46 C), representing a decline of approximately 50% in the diversity of genera compared to the brachiopods of the Maecuru Formation. Although we observed a considerable decrease in the Ererê Formation, representatives from almost all orders previously documented in the Maecuru Formation remain, except for Spiriferinida and Strophomenida (Figure 47). The fauna of the Ererê Formation is attributed to deeper water conditions than the Maecuru Formation (Figure 46 A), related to a transgression, in addition to warmer climatic conditions, suggested by the presence of thin dolomitic beds and some calcitic cementations (Caputo 1984).

Most Devonian extinction events are related to rapid regressive–transgressive pulses. The Choteč and Kačak events are examples of these global extinctions (House 2002, Becker *et al.* 2012).

In the Paraná Basin, studies recognize two faunistic declines of marine invertebrates related to regressions and transgressions. The first occurred between late Pragian – early Emsian, with the extinction of eight brachiopod species (Bosetti *et al.* 2012). This decline would be related with the late Pragian – early Emsian regression and the transgression in the early late

Emsian (Bosetti *et al.* 2012). The second decline was identified by Horodyski *et al.* (2013) in layers from the São Domingos Formation, with a reduction of 57 genera of marine invertebrates, this being the possible record of the global Kačak extinction event in the Paraná Basin. The authors relate this decline with the transgression in the Eifelian–Givetian (Horodyski *et al.* 2013).

Of the sixteen brachiopod species from the Ererê Formation, seven are remnants from the Maecuru Formation, and nine are new species. This first decline is likely related to the relative sea-level rise, which caused environmental disruptions and a drastic ecological shift responsible for the disappearance of twenty-one brachiopod species. These changes enabled new species to occupy the affected area through speciation or immigration (Krebs 2014, Bosetti *et al.* 2011), justifying the emergence of the six new species in the Ererê Formation.

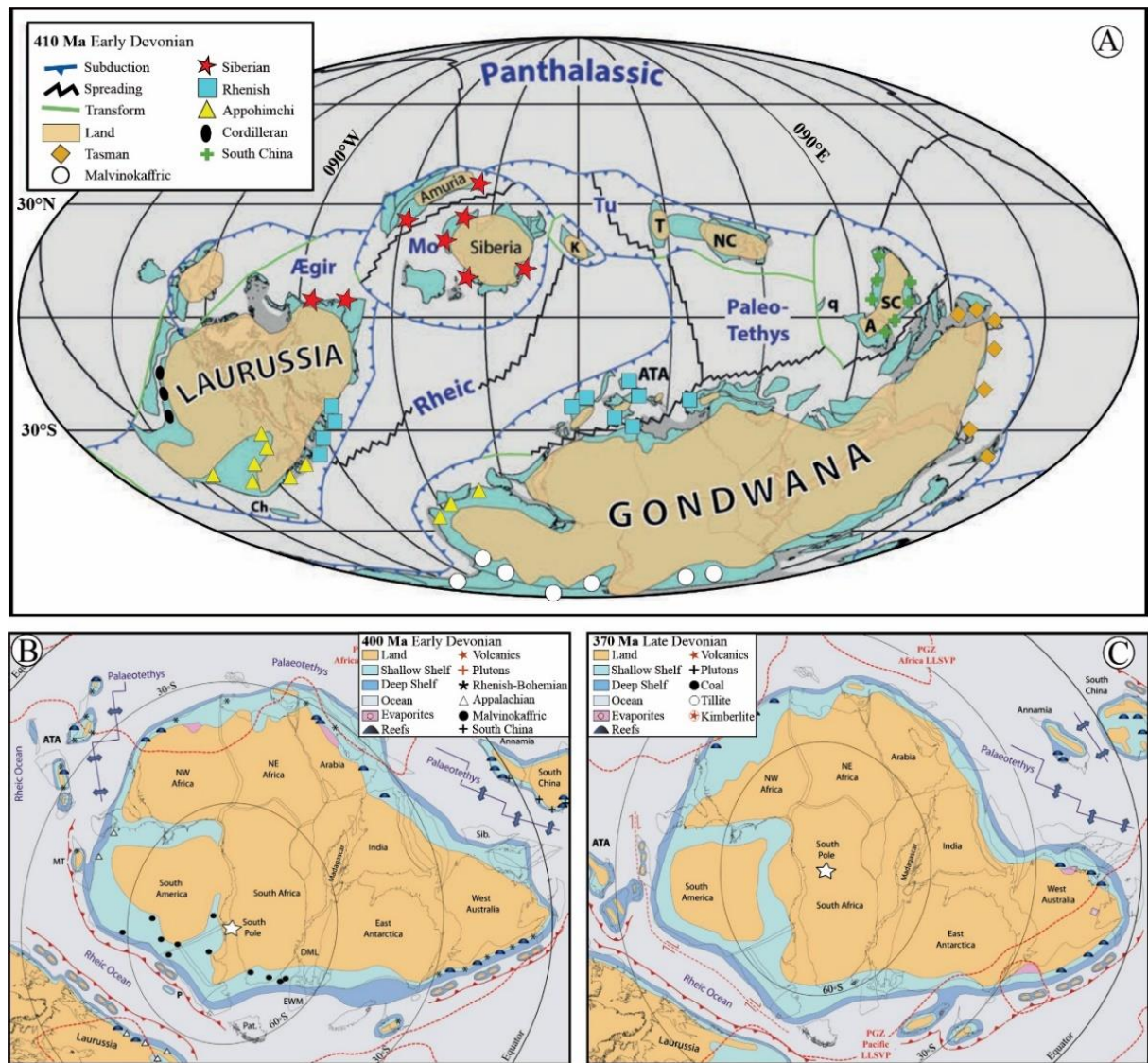


Figure 48- A) paleogeography at 410 Ma. (Torsvik & Cocks 2016); B) Gondwana at 400 Ma. and C) Gondwana at 370 Ma. (Torsvik & Cocks 2013).

Stage 3: In the Frasnian (Figure 48 C), there was a second diversity decline of Devonian brachiopods in the Amazonas Basin, as recorded in the Barreirinha Formation when the Phylum was almost extinct, with only records of Lingulida, Spiriferida, and Orthothetida (Figure 47).

The dark sedimentary facies (indicative of dysoxia or anoxia), with a benthic fauna that is poor in diversity or non-existent, generally characterize the twenty Paleozoic extinctions (House 2002).

A major global transgression started in the Late Devonian (Caputo 1984). The brachiopods from the Barreirinha Formation occur in layers of black shale with anoxic or dysoxic (oxygen-deprived) conditions of high stress attributed to an offshore environment. Caputo (1984) believes that in this period, the Amazonas basin experienced the deepest marine conditions in its history. Such conditions do not favor the proliferation of benthic fauna rich in diversity (Copper 1977, Melo 1985). Only a few organisms adapted, which explains the second diversity decline.

The subdivisions of the Famennian, as formally established by the Devonian Stratigraphy Subcommittee (SDS) into four substages (Lower, Middle, Upper, and Uppermost), are not recognized in the Amazonas Basin (Becker *et al.* 2012, Cunha *et al.* 2007). In the Famennian, the Amazonas Basin experienced a glacial period characterized by the diamictites from the Curiri Formation (Caputo 1984). Brachiopods are absent in this unit. It is possible that the extreme glacial conditions were an obstacle to the survival of the Phylum.

7.7 CONCLUSIONS

The Amazonas Basin has a higher diversity of Devonian brachiopod genera among Brazilian sedimentary basins (Paraná, Parnaíba, Parecis, and Jatobá basins). In quantitative analysis, the number of the genera recorded in the Manacapuru, Maecuru, Ererê, and Barreirinha formations follows the global trend of the Phylum in the Devonian in terms of diversity. There was a significant increase in the variety of genera during the Lochkovian – early Eifelian representing the apex of brachiopod diversity of the Devonian in the Amazonas Basin. The first decline occurred between early Eifelian – late Eifelian when about 50% of brachiopod genera became extinct in the Amazonas Basin. Subsequently, a second decline occurred between the late Eifelian – early Frasnian. The variation in diversity of brachiopod genera throughout the Devonian in the Amazonas Basin is related to factors such as the geographic position of the paleocontinents (Gondwana and Laurussia), ocean temperatures, oxygen availability, and variations in global relative sea levels.

During the Lochkovian, the Amazonas Basin was closer to Laurasia, the environmental conditions were marine, the climate was not as severe as at the beginning of the Silurian, and these conditions probably enabled the migration of cosmopolitan larvae of *Orbiculoidea* from Laurasia to the Amazonas Basin first, as shown by the records of *O. baini*, *O. bodenbenderi*, and *O. excentrica* from the Manacapuru Formation. The peak of brachiopod diversity is recorded in the Maecuru Formation (early Eifelian) in a proximal marine environment, where global ocean temperatures were increasing, and the Amazonas Basin was between subtropical latitudes 30°S and 60°S. The first decline is related to deeper environmental conditions (resulting from a transgression) and higher temperatures than those in the early Eifelian (Maecuru Formation). The Barreirinha Formation registers the second decline (early Frasnian). A major global transgression occurred in the Late Devonian. In this period, the Amazonas basin experienced the deepest marine conditions in its history. The brachiopods from the Barreirinha Formation occur in layers of black shale with anoxic or dysoxic (oxygen-deprived) conditions of high stress attributed to an offshore environment, which explains the low diversity of brachiopod fauna in this formation. In the Famennian, the Amazonas Basin experienced a glacial period (Curiri Formation). Brachiopods are absent in this unit. It is possible that the extreme glacial conditions were an obstacle to the survival of the Phylum.

ACKNOWLEDGMENTS

The authors would like to thank the Earth Sciences Coordination of the Museu Paraense Emilio Goeldi for providing the necessary laboratory infrastructure and access to the paleontological collection, which made this research possible. We thank Dr. Lisa Amati (New York State Museum) and Dr. Rafael Costa da Silva (CPRM) for providing information on the brachiopods deposited in the collections, of which both are curators. We are very grateful to the Coordination of Superior Level Staff Improvement (CAPES) for funding this research with a master scholarship (financing code 001) awarded to the first author, to the Programa de Pós-Graduação em Geologia e Geoquímica (PPGG) of the Federal University of Pará (UFPA) for logistic and financial support and the Brazilian Council of Science and Technological Development (productivity fellowships grants 307424/2019–7 and 305031/2022–8 to M.I.F.R.).

REFERENCES

- Albuquerque OR. 1922. Reconhecimentos geológicos no valle do Amazonas (Campanhas de 1918 e 1919). Boletim do Serviço Geológico e Mineralógico do Brasil. 3: 1–83
- Bastos AA & Moura P. 1929. Reconhecimentos geológicos no rio Maecuru. *In*: Oliveira E. P. Relatório annual do director do Serviço Geológico e Mineralógico do Brasil. 21–29.

- Becker RT, Gradstein FM, Hammer O. 2012. Chapter 22 – The Devonian period. In Gradstein FM, Ogg JG, Schmitz MD, Ogg GM. (eds), *The Geologic Time Scale*, Elsevier. 559–601. <https://doi.org/10.1016/B978-0-444-59425-9.00022-6>
- Bosetti EP, Grahn Y, Horodyski RS, Mauller PM, Breuer P, Zabini C. 2011. An earliest Givetian “Lilliput effect” in the Paraná Basin, and the collapse of the Malvinokaffric shelly fauna. *Paläontologische Zeitschrift*. 85, 49–65. <https://doi.org/10.1007/s12542-010-0075-8>
- Bosetti EP, Grahn Y, Horodyski RS, Mauller PM. 2012. The first recorded decline of the Malvinokaffric Devonian fauna in the Parana´ Basin (southern Brazil) and its cause; taphonomic and fossil evidences. *Journal of South American Earth Sciences*. 37: 228–241. <https://doi.org/10.1016/j.jsames.2012.02.006>
- Boucot AJ & Blodgett RB. 2001. Silurian–Devonian biogeography. In Brunton CHC, Cocks LRM, Long SL (eds.), *Brachiopods Past and Present*. London: Taylor and Francis. 335–344. <https://doi.org/10.1017/S0016756803247841>
- Boucot AJ, Johnson JG, Talent JA. 1969. Early Devonian Brachiopod Zoogeography. *Geological Society of America Special Paper*. 119: 1–113. <https://doi.org/10.1130/SPE119>
- Boucot AJ, Rowell AJ, Racheboeuf P, Pereira E, Melo JHG, Siqueira LP. 2001. Position of the Malvinokaffric Realm’s northern boundary (Early Devonian) based on newly discovered brachiopods from the Parecis Basin (Brazil). *Journal of the Czech Geological Society*. 46: 109–120.
- Boucot AJ. 1971. Malvinokaffric Devonian marine community distribution and implications for Gondwana. *Anais da Academia Brasileira de Ciências*. 43: 23–49.
- Boucot AJ. 1975. *Developments in Paleontology and Stratigraphy 1: Evolution and Extinction Rate Controls*. Elsevier Scientific Publishing Company, Amsterdam. 1–427.
- Caputo MV & Crowell JC. 1985. Migration of glacial centers across Gondwana during Paleozoic Era. *Geological Society of America Bulletin*. 96(8): 1020–1036. [https://doi.org/10.1130/0016-7606\(1985\)96<1020:MOGCAG>2.0.CO;2](https://doi.org/10.1130/0016-7606(1985)96<1020:MOGCAG>2.0.CO;2)
- Caputo MV. 1984. *Stratigraphy, tectonics, paleoclimatology and paleogeography of northern basins of Brazil*. Califórnia, Universidade da Califórnia.
- Carozzi AV, Pamplona HRP, Castro JC, Contreiras CJA. 1973. Ambientes Depositionais e Evolução Tecto-sedimentar da Seção clástica Paleozoica da Bacia do Médio Amazonas. In: *Anais do 28º Congresso Brasileiro de Geologia*. Aracaju. 279–314.
- Carvalho RG. 1975. Braquiópodes Devoniano da Bacia do Amazônica, orthida, stophomenida, spiriferida e terebratulida. *Boletim do Museu Paraense Emílio Goeldi, Geologia*. 21: 1–22.
- Carvalho RGD. 1972. *Braquiópodes devonianos da Bacia do Amazonas*. São Paulo, SP. Tese de Doutorado. Instituto de Geociências, Universidade de São Paulo, 1–140.
- Clarke JM. 1899. A fauna siluriana superior do Rio Trombetas: Estado do Pará, Brazil. *Archivos do Museu Nacional*. 1–32.

Clarke JM. 1913. Fósseis devonianos do Paraná. Monographias do Serviço Geológico e Mineralógico do Brasil, Rio de Janeiro. 1: 1–353.

Copper P. 1977. Paleolatitudes in the Devonian of Brazil and the Frasnian-Famennian mass extinction. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 21: 165–207. [https://doi.org/10.1016/0031-0182\(77\)90020-7](https://doi.org/10.1016/0031-0182(77)90020-7)

Corrêa LFA & Ramos MIF. 2021. Discinoids (Brachiopoda: Lingulata) from the upper Manacapuru Formation (Early Devonian), south border of Amazonas Basin, Brazil. *Journal of South American Earth Sciences*. 105:102960. <https://doi.org/10.1016/j.jsames.2020.102960>

Cunha P. R. C. 2000. Análise Estratigráfica dos sedimentos Eo/Mesodevonianos da porção ocidental da Bacia do Amazonas sob a ótica da estratigrafia de Seqüências no interior cratônico. Dissertação de Mestrado, Universidade Federal do Rio Grande do Sul. 1–342.

Cunha PRC, Gonzaga FG, Coutinho LFC, Feijó FJ. 1994. Bacia do Amazonas. *Boletim de Geociências da PETROBRAS*. 8: 47–55.

Cunha PRC, Melo JHG, Silva OB. 2007. Bacia do Amazonas. *Boletim Geociências Petrobras*. 15: 227–251.

Derby OA. 1877. Contribuição para a geografia da região do Baixo Amazonas. *Archivos do Museu Nacional*. 3: 77–104.

Fernandes ACS & Scheffler SM. 2014. A Comissão Geológica do Império e os crinoides fósseis do Museu Nacional/UFRJ, Rio de Janeiro, Brasil. *Filosofia e História da Biologia*. 9(2): 121–139.

Finnegan S, Bergmann K, Eiler JM, Jones DS, Fike DA, Eisenman I, Hughes NC, Tripathi AK, Fisher WW. 2011. The magnitude and duration of late Ordovician–early Silurian glaciation. *Science*. 331(6019): 903–906. doi: 10.1126/science.1200803

Fonseca VMM & Ponciano LCMO. 2011. Braquiópodes do Devoniano Médio das bacias do Amazonas e Parnaíba. In: Carvalho I. S. (Org.). *Paleontologia: Cenários de Vida*. Interciência. 1(4): 169–190.

Fonseca VMM. 2004. Chonetoidea (Brachiopoda) do Devoniano Médio das Bacias do Amazonas e Parnaíba, Brasil. *Archivos do Museu Nacional*. 62: 193–215.

Grahn Y & Caputo MV. 1992. Early Silurian glaciations in Brazil. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 99: 9–15. [https://doi.org/10.1016/0031-0182\(92\)90003-N](https://doi.org/10.1016/0031-0182(92)90003-N)

Grahn Y & Melo JHG. 1990. Bioestratigrafia dos quitinozoários do Grupo Trombetas nas faixas marginais da Bacia do Amazonas. Rio de Janeiro: PETROBRAS/CENPES/DIVEX/SEBIPE. Report produced for the Eletrobras Eletronort. 1–43.

Grahn Y & Melo JHG. 2004. Integrated Middle Devonian chitinozoan and miospore zonation of the Amazonas Basin, northern Brazil. *Revue de micropaléontologie*. 47(2): 71–85. <https://doi.org/10.1016/j.revmic.2004.03.001>

Grahn Y. 2005. Silurian and Lower Devonian chitinozoan taxonomy and biostratigraphy of the Trombetas Group, Amazonas Basin, northern Brazil. *Bulletin of Geosciences, Prague*. 80(4): 245–276.

Harper DAT, Popov LE, Holmer LE. 2017. Brachiopods: origin and early history. *Palaeontology*. 60(5): 609–631. <https://doi.org/10.1111/pala.12307>

Horodyski RS, Holz M, Grahn CY, Bosetti EP. 2013. Remarks on the sequence stratigraphy and taphonomy of the relictual Malvinokaffric fauna during the Kačák event in the Paraná Basin, Brazil. *International Journal of Earth Sciences*. 103: 367–380. <https://doi.org/10.1007/s00531-013-0954-9>

House MR. 2002. Strength, timing and cause of mid-Paleozoic extinctions. *Palaeogeography, Palaeoclimatology, Palaeoecology*. 181: 5–25. [https://doi.org/10.1016/S0031-0182\(01\)00471-0](https://doi.org/10.1016/S0031-0182(01)00471-0)

Johnson ME. 2006. Relationship of Silurian sea-level fluctuations to oceanic episodes and events. *GFF*. 128(2): 115–121. <https://doi.org/10.1080/11035890601282115>

Katzer F. 1897. Das Amazonas-Devon und seine Beziehungen zu den anderen Devon-gebieten der Erde. Verlag der Königl. Böhmisches Gesellschaft der Wissenschaften. 47:1–50.

Katzer F. 1903. Grundzüge der geologie des unteren Amazonasgebietes (des Staates Pará in Brasilien). Leipzig, Max Weg. 1–298.

Katzer F. 1933. Geologia do estado do Pará, (Brasil). *Boletim do Museu Paraense Emílio Goeldi de História Natural e Etnografia*. 9: 1–269.

Kegel W. 1953. Contribuição para o estudo do Devoniano da bacia do Parnaíba, Brasil. *Boletim da Divisão de Geologia e Mineralogia*. 141:1–48.

Krebs CJ. 2014. *Ecology: the experimental analysis of distribution and abundance*. Pearson. 6:1–645

Ludwig G. 1964. Divisão estratigráfico-faciológica do Paleozóico da Bacia Amazônica. PETROBRAS, Ciência Técnica Petróleo, Seção: Exploração de petróleo. 1: 1–72.

Macambira EMB, Rezende NGAM, Calderaro RCB, Assis NP. 1977. Projeto Sulfetos de Altamira – Itaituba. Arquivo técnico, DGM n° 2679. Belém, DNPM/CPRM.

Melo JHG & Loboziak S. 2003. Devonian – Early Carboniferous miospore biostratigraphy of the Amazon Basin, Northern Brazil. *Review of Palaeobotany and Palynology*. 124: 131–202. [https://doi.org/10.1016/S0034-6667\(02\)00184-7](https://doi.org/10.1016/S0034-6667(02)00184-7)

Melo JHG. 1985. A província Malvinocáfrica no Devoniano do Brasil: estado atual dos conhecimentos. Rio de Janeiro, UFRJ.

Moura PD. 1938. Geologia do baixo Amazonas. *Boletim do Serviço Geológico e Mineralógico*, 91:1–55.

Oliveira EP. 1930. Estado do Pará. Relatório anual do director do Serviço Geológico e Mineralógico do Brasil, anno 1929. 9–23.

Penn-Clarke CR & Harper DAT. 2020. Early-Middle Devonian brachiopod provincialism and bioregionalization at high latitudes: A case study from southwestern Gondwana. *Geological Society of America Bulletin*, 133(3–4): 819–836. <https://doi.org/10.1130/B35670.1>

Ponciano LCMO, Machado DMC, Faria ACG, Maciel AC, Matos J, Novaes M. 2007b. Life habits of Gastropoda and Bellerophonitida of the Maecuru formation, Middle Devonian, Amazonas Basin, Brazil. *Anuário do Instituto de Geociências - UFRJ*. 30(1): 197–203. https://doi.org/10.11137/2007_1_197-203

Ponciano LCMO, Machado DMC, Souza AR, Faria ACG, Vieira ACM. 2007a. Hábitos de Vida da Associação “*Schuchertella*” *agassizi* – *Pthychopteria eschwegei*, Formação Maecuru, Devoniano, Bacia do Amazonas, Brasil. *Anuário do Instituto de Geociências - UFRJ*. 30(1): 135–144. https://doi.org/10.11137/2007_1_135-144

Rathbun R. 1874 – On the devonian Brachiopoda of Ererê, Province of Pará, Brazil. *Buffalo Society of Natural Sciences, Bulletin, Buffalo*. 1: 236–261.

Rathbun R. 1878. The Devonian Brachiopoda of the Province of Pará, Brazil. *Boston Society of Natural History*. 20: 14–39.

Ross CA & Ross JRP. 1988. Late Paleozoic transgressive-regressive deposition. In: Wilgus CK, Hastings BS, Kendall CG, Posamentier HW, Ross CA, Van Wagoner JC. (Eds.). *Sea-Level Changes-Na Integrated Approach*, 42. *SEPM Special Publication*. 227–247.

Silva MB, Videira-Santos R, Scheffler SM, Fernandes ACS. 2019. In: *Anais do XXVI Congresso Brasileiro de Paleontologia*. Campinas. Galoá. 2: 118543.

Tomassi HZ, Almeida CM, Ferreira BC, Brito MB, Barberi M, Rodrigues GC, Teixeira SP, Capuzzo JP, Gama-Júnior JM, Santos MGKG. 2015. Preliminar results of paleontological salvage at Belo Monte Powerplant construction. *Brazilian Journal of Biology*. 75(3): 277–289. <https://doi.org/10.1590/1519-6984.1714BM>

Torsvik TH & Cocks LRM. 2013. Gondwana from top to base in space and time. *Gondwana Research*. 24: 999–1030. <https://doi.org/10.1016/j.gr.2013.06.012>

Torsvik TH & Cocks LRM. 2016. *Earth history and paleogeography*. Cambridge University Press. 1–317. <https://doi.org/10.1017/9781316225523>

Wallmann K. 2004. Impact of atmospheric CO₂ and galactic cosmic radiation on Phanerozoic climate change and the marine δ¹⁸O record. *Geochemistry, Geophysics, Geosystems*. 5: 1–29. <https://doi.org/10.1029/2003GC000683>

Williams A, Brunton CHC, Carlson SJ, Alvarez F, Ansell AD, Baker PG, Bassett MG, Blodgett RB, Boucot AJ, Carter JL, Cocks LRM, Cohen BL, Copper P, Curry GB, Cusack M, Dagens AS, Emig CC, Gawthrop AB, Gourvenec R, Grant RE, Harper DAT, Holmer LE, Hong-Fei H, James MA, Yu-Gan J, Johnson JG, Laurie JR, Lazarev S, Lee DE, Lüter C, Mackay S, MacKinnon DI, Manceido MO, Mergl M, Owen EF, Peck LS, Popov LE, Racheboeuf PR, Rhodes MC, Richardson JR, Jia-Yu R, Rubel M, Savage NM, Smirnova TN, Dong-li S, Walton

D, Wardlaw B, Wright AD. 2007. Treatise on invertebrate paleontology. Part H. Brachiopoda (Revised) 6. Geological Society of America & University of Kansas Press. 2321–3226

Zabini C, Denezine M, Rodrigues LCDS, Lívio RDO, Adôrno RR, Carmo D, Assine ML. 2021. Fossil diversity and taphonomy of glacial and post-glacial lower paleozoic strata, NE Paraná Basin, Brazil. *Journal of South American Earth Sciences*. 111: 103470. <https://doi.org/10.1016/j.jsames.2021.103470>

Zabini C, Furtado-Carvalho AB, Carmo D, Assine ML. 2019. A new discinoid *Kosoidea australis* sp. nov. from the Iapó and Vila Maria Formations, NE Paraná Basin, Brazil. *Historical Biology*. 33(4): 534–542. <https://doi.org/10.1080/08912963.2019.1648447>

Zhang Y, Lee S, Wu HT, He WH. 2018. Palaeobiogeographical distribution of Orbiculoidea (Brachiopoda, Discinoidea) responding to global climatic and geographical changes during the Palaeozoic. *Paleontology*. 61(2): 221–234. <https://doi.org/10.1111/pala.12339>

CAPÍTULO 8 CONSIDERAÇÕES FINAIS

O estudo taxonômico dos braquiópodes da parte superior da Formação Manacapuru (Lochkoviano), borda sul da Bacia do Amazonas, coletados no município de Vitória do Xingu – PA, norte do Brasil, permitiu a identificação de dois gêneros, *Orbiculoidea* e *Schellwienella*. Dentre o material estudado, *Orbiculoidea* tem a maior diversidade, totalizando cinco espécies, sendo *Orbiculoidea baini*, *Orbiculoidea bodenbenderi* e *Orbiculoidea excentrica*, além de duas novas espécies *Orbiculoidea xinguensis* sp. nov. e *Orbiculoidea katzeri* sp. nov.

As espécies *O. baini*, *O. bodenbenderi* e *O. excentrica* são registradas pela primeira vez na Formação Manacapuru e no Norte do Brasil, sendo estes os registros mais antigos (Lochkoviano) na América do Sul. Sua presença na região pode ser explicada por dois motivos: a proximidade da Bacia do Amazonas, localizada no noroeste de Gondwana durante o Devoniano Inferior, com o paleocontinente Laurussia (onde são registradas a maioria das ocorrências de *Orbiculoidea* durante o Siluriano), favorecendo o intercâmbio específico entre essas duas regiões geográficas; e a elevação global do nível do mar durante esse período, que inundou grande parte do noroeste de Gondwana, resultando na presença de mares rasos na Bacia do Amazonas, representados por sedimentos marinhos na parte superior da Formação Manacapuru. Essas condições promoveram a colonização de braquiópodes inarticulados durante o Devoniano Inferior no norte do Brasil.

Propomos também a nova espécie *Schellwienella amazonensis* sp. nov., Família Pulsiiidae Cooper & Grant, 1974, que junto com *Schellwienella marcidula* da Formação Bois d’Arc (Lochkoviano), EUA, são os registros mais antigos do gênero. Nas formações Maecuru e Ererê (Bacia do Amazonas), há registros de *Schuchertella agassizi*. Na Bacia do Paraná, esta espécie foi revisada, onde os autores propuseram uma nova espécie, *Schellwienella clarkei* Rezende *et al.* 2021. É necessário que haja uma revisão de *Schuchertella agassizi* da Bacia do Amazonas, levando em consideração principalmente as características morfológicas internas e as micro-ornamentações. Enquanto não ocorrer a revisão, *Schellwienella amazonensis* sp. nov. é considerada a única ocorrência do gênero na Bacia do Amazonas.

No Devoniano, *Schellwienella* ocorreu em todos os estágios (Lochkoviano, Praguiano, Emsiano, Eifeliano, Givetiano, Frasniano e Famenniano), principalmente nos ambientes marinhos siliciclásticos de Gondwana, transitando entre as latitudes temperadas e polares. Já no Carbonífero, sua distribuição estratigráfica foi mais curta, restrita ao intervalo Tournaisiano-Viséano, e com preferência por ambientes de águas quentes e plataformas carbonáticas, típicas de baixas latitudes.

Quantitativamente, o número de gêneros registrados nas formações Manacapuru, Maecuru, Erere e Barreirinha seguem a tendência global do filo no Devoniano em termos de diversidade. Houve um aumento significativo na variedade de gêneros durante o Lochkoviano – Eoiefeliano representando o ápice da diversidade de braquiópodes do Devoniano na Bacia do Amazonas (estágio 1). O primeiro declínio ocorreu entre o Eoiefeliano – Neoeiefeliano quando cerca de 50% dos gêneros de braquiópodes foram extintos na Bacia do Amazonas (estágio 2). Posteriormente, um segundo declínio ocorreu entre o Neoeiefeliano – Eofrasniano (estágio 3). Essa variação na diversidade de gêneros nas unidades devonianas da Bacia do Amazonas está relacionada a fatores como a posição geográfica dos paleocontinentes (Gondwana e Laurussia), temperaturas dos oceanos, disponibilidade de oxigênio e principalmente com as variações do nível relativo do mar.

O pico da diversidade de braquiópodes ocorreu no Eoiefeliano (Formação Maecuru), quando a Bacia do Amazonas estava entre as latitudes subtropicais 30°S e 60°S, sob condições marinhas rasas e frias, justificadas pela ausência de carbonatos, evaporitos e recifes na região (estágio 1). O primeiro declínio da diversidade é registrado na Formação Ererê (Neoeiefeliano), atribuído a um clima mais quente e águas mais profundas do que na Formação Maecuru (estágio 2). Durante o Frasniano, houve um segundo declínio da diversidade de braquiópodes na Bacia do Amazonas (Formação Barreirinha). Uma grande transgressão global ocorreu no final do Devoniano. Nesse período, a Bacia do Amazonas experimentou as condições marinhas mais profundas de sua história, registradas nas camadas de folhelhos negros (*offshore*) da Formação Barreirinhas, atribuídas a um ambiente disóxico a anóxico de alto estresse, o que explica a baixa diversidade de braquiópodes nessa unidade (estágio 3). No decorrer do Fameniano, a Bacia do Amazonas passou por um período glacial (Formação Curiri), o que possivelmente impediu o registro dos braquiópodes nesta unidade; é possível que as condições glaciais extremas tenham sido um obstáculo à sobrevivência do filo, uma vez que o grupo já havia se adaptado para condições de ambientes tropicais e de águas quentes.

REFERÊNCIAS

- Almeida F.F.M. 1967. Origem da plataforma brasileira. *Boletim da divisão de Geologia e Mineralogia*, Rio de Janeiro, **241**: 1-36.
- Bassett M.G. & Bryant C. 2006. A Tournasian Brachiopod fauna from south-east Wales. *Palaeontology*, **49**: 485-535.
- Bennacef A., Beuf S., Biju-Duval B., Charpal O., Gariel O., Rognon P. 1971. Example of Cratonic Sedimentations: Lower Paleozoic of Algerian Sahara. *The American Association of Petroleum Geologists Bulletin*, **55**: 2225-2245.
- Bosetti E.P., Horodyski R.S., Zabini C., Matsumura W.M.K., Penteadó, A.C. 2010. Ocorrência de fenótipos subnormais no topo da Formação Ponta Grossa (Devoniano), Tibagi, estado do Paraná, Brasil: implicações tafonômicas e Paleossinecológicas. *Boletim do Museu Paraense Emílio Goeldi*, **5**(2): 135-149.
- Boucot A.J. 1971. Malvinokaffric Devonian marine community distribution and implications for Gondwana. *Anais da Academia Brasileira de Ciências*, **43**: 23-49.
- Boucot A.J. 1975. Developments in Palaeontology and Stratigraphy. *Evolution and Extinction Rate Controls*, **1**:1-427.
- Boucot A.J. 1985. Late Silurian–Early Devonian biogeography, provincialism, evolution and extinction. *In*: Chaloner W.G., Lawson J.D. *Evolution and Environment in the Late Silurian and Early Devonian*. London, Royal Society, p. 323-339.
- Boucot A.J. 1988. Devonian biogeography: an update. *In*: McMillan N.J., Embry A.F., Glass D.J., (Eds.). *Devonian of the World, Volume III: Palaeontology, Palaeoecology and Biostratigraphy*. *In*: 2nd International Symposium on the Devonian System, Calgary. p. 211-227.
- Boucot A.J. & Blodgett R.B. 2001. Silurian-Devonian biogeography. *In*: Brunton C.H.C., Cocks L.R.M., Long S.L. (eds.). *Brachiopods past and present*. [S.l.]. London, Taylor and Francis Publishers, p. 335-344.
- Boucot A.J., Johnson J.G., Talent J.A. 1969. Early Devonian Brachiopod Zoogeography. *Geological Society of America Special Paper* **119**: 1-113.
- Boucot A.J., Rowell A.J., Racheboeuf P.R., Pereira E., Melo J.G., Siqueira L.P. 2001. Position of the Malvinokaffric Realm's northern boundary (Early Devonian) based on newly discovered brachiopods from the Parecis Basin (Brazil). *Journal of the Czech Geological Society*, **46**(3-4): 109-120.
- Boucot A.J., Xu C., Scotese C.R. 2013. Devonian climatic summary. *In*: Boucot A.J., Xu C., Scotese C.R., Morley R.J. *Phanerozoic Paleoclimate: An Atlas of Lithologic Indicators of Climate*. Tulsa, Society for Sedimentary Geology (SEPM), p. 99-126.
- Brito Neves B.B. & Almeida F.F.M. 2003. A Evolução dos Crátons Amazônico e São Francisco comparada com homólogos do hemisfério norte – 25 anos depois. *In*: 8^o Simpósio de Geologia da Amazônia, Manaus. *Anais*[...], p. 13–17.

Camacho H.H. & Longobucco M.I. 2007. Los Invertebrados fósiles. *Fundación de Historia Natural Félix Azara*, **1**: 1-512.

Caputo M.V. 1984. *Stratigraphy, tectonics, paleoclimatology and paleogeography of Northern basins of Brazil*. PhD Teses, Universidade da California, 583p.

Caputo M.V. & Andrade F.G. 1968. *Geologia em semidetalle do flanco sul da Bacia Amazônica: entre os rios Cupari e Abacaxis*. Petrobras – Setor de Exploração, Rio de Janeiro. p. 1-141. (Relatório interno).

Caputo M.V. & Crowell J.C. 1985. Migration of glacial centers across Gondwana during Paleozoic Era. *Geological Society of America Bulletin*, **96**(8): 1020-1036.

Caputo M.V. & Lima E.C. 1984. Estratigrafia, idade e correlação do Grupo Serra Grande-bacia do Parnaíba. In: 33º Congresso Brasileiro de Geologia, Rio de Janeiro. *Anais[...]*, p. 740-753.

Caputo M.V., Rodrigues R., Vasconcelos D.N.N. 1971. *Litoestratigrafia da Bacia do Amazonas*. Petrobrás, Rio de Janeiro. p. 130-4054. (Relatório Interno).

Carbonaro F.A., Comniskey J.C., Corral H.S., Ghilardi R.P. 2018. *Orbiculoidea baini* and *Orbiculoidea excentrica* (Brachiopoda, Discinidae) from the Middle Devonian (Alto Garças Sub-basin, Paraná Basin) of Caiapônia, Goiás (Brazil). *Série Científica*, **18**(4): 11-20.

Carlson S.J. 2016. The evolution of Brachiopoda. *Annual Review of Earth and Planetary Sciences*, **44**: 409-438.

Carozzi A.V., Pamplona H.R.P., Castro J.C., Contreiras C.J.A. 1973. Ambientes Depositionais e Evolução Tecto-sedimentar da Seção clástica Paleozoica da Bacia do Médio Amazonas. In: 28º Congresso Brasileiro de Geologia, Aracaju. *Anais[...]*, p. 279-314.

Carvalho R.G. 1975. Braquiópodes Devoniano da Bacia do Amazônica, orthida, stophomenida, spiriferida e terebratulida. *Boletim do Museu Paraense Emílio Goeldi*. Geologia, **21**: 1-22.

Carvalho R.G.D. 1972. *Braquiópodes devonianos da Bacia do Amazonas*. PhD Teses. Instituto de Geociências, Universidade de São Paulo, São Paulo, SP.140p.

Clarke J.M. 1899. A fauna siluriana superior do rio Trombetas: Estado do Pará, Brazil. *Archivos do Museu Nacional*, p. 1-32.

Clarke J.M. 1913. Fósseis devonianos do Paraná. *Monographias do Serviço Geológico e Mineralógico do Brasil*, Rio de Janeiro, **1**: 1-353.

Clarkson E.N.K. 1992. Invertebrate palaeontology and evolution. *Champman and Hall*, **3**: 1-153.

Cocks L.R.M. & Torsvik T.H. 2002. Earth geography from 500 to 400 million years ago: A faunal and palaeomagnetic review. *Journal of the Geological Society*, **159**(6): 631-644.

Comniskey J.C. & Bosetti E.P. 2017. Discinoids of the Malvinokaffric Realm: Stratigraphic, Paleogeographical Distribution and Systematic Review. *Terr@Plural*, **11**(2): 175-192.

- Comniskey J.C., Bosetti E.P., Horodyski R.S. 2016. Taphonomic aspects and the Lilliput Effect on Devonian discinoids of the Paraná Basin, Apucarana Sub-basin, Brazil. *Gaea: Journal of Geoscience*, **9**(1): 55-64.
- Copper P. 1977. Paleolatitudes in the Devonian of Brazil and the Frasnian-Famennian mass extinction. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **21**(3): 165-207.
- Cordani U.G. & Brito Neves B.B. 1982. The Geologic Evolution of South America during the Archean and Early Proterozoic. *Revista Brasileira de Geociências*, **12**(3): 78-88.
- Cordani U.G., Tassinari C.C.G., Teixeira W., Basei M.A.S., Kawashita K. 1979. Evolução Tectônica da Amazônia com base nos dados geocronológicos. In: 2º Congresso Geológico Chileno, p. 137-148.
- Corrêa L.F.A. 2020. *Taxonomia de brachiopoda (Família Discinidae Gray, 1840) da Formação Manacapuru (Siluro-Devoniano), Bacia do Amazonas, Sudoeste do Pará*. MS Dissertation, Universidade Federal do Pará, Belém. 108p.
- Corrêa L.F.A. & Ramos M.I.F. 2021. Discinoids (Brachiopoda: Lingulata) from the upper Manacapuru Formation (Early Devonian), south border of Amazonas Basin, Brazil. *Journal of South American Earth Sciences*, **105**: 102960.
- Corrêa L.F.A. & Ramos M.I.F. 2023. Relationships between brachiopod fauna (Lochkovian–Frasnian) from northwest Gondwana (Amazonas Basin) and environmental changes during the Devonian. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **629**: 111803.
- Cunha P.R.C. 2000. *Análise Estratigráfica dos sedimentos Eo/Mesodevonianos da porção ocidental da Bacia do Amazonas sob a ótica da estratigrafia de Seqüências no interior cratônico*. MS Dissertation, Universidade Federal do Rio Grande do Sul, Porto Alegre. 263p.
- Cunha P.R.C., Gonzaga F.G., Coutinho L.F.C., Feijó F.J. 1994. Bacia do Amazonas. *Boletim de Geociências da Petrobras*, **8**: 47-55.
- Cunha P.R.C., Melo J.H.G., Silva O.B. 2007. Bacia do Amazonas. *Boletim de Geociências da Petrobras*, **15**: 227-251.
- Daemon R.F. & Contreiras C.S.A. 1971. Zoneamento palinológico da Bacia do Amazonas. In: 25º Congresso Brasileiro de Geologia, São Paulo, *Anais[...]*, v.3, p. 29-92.
- Derby O.A. 1877. Contribuição para a geografia da região do Baixo Amazonas. *Archivos do Museu Nacional*, **3**: 77–104.
- Dowding E.M. & Ebach M.C. 2018. An interim global bioregionalisation of Devonian areas. *Palaeobiodiversity and Palaeoenvironments*, **98**(4): 527-547.
- Dowding E.M. & Ebach M.C. 2019. Evaluating Devonian bioregionalization. *Paleobiology*, **45**(4): 636– 651.
- Dowding E.M., Ebach M.C., Madroviev E.V. 2021. Validating marine Devonian Biogeography: A study in bioregionalization. *Paleontology*, **65**(1): 12578.

Emig C.C. 2003. Proof that *Lingula* (Brachiopoda) is not a living-fossil, and emended diagnoses of the Family Lingulidae. *Carnets de Géologie / Notebooks on Geology*, **1**: 1-8.

Emig C.C., Bitner M.A., Alvarez F. 2013. Phylum Brachiopoda. In: Zhang, Z.Q. (Ed.) Animal Biodiversity: An Outline of Higher-level Classification and Survey of Taxonomic Richness. *Zootaxa*, **3703**(1): 75-78.

Finnegan S., Bergmann K., Eiler J.M., Jones D.S., Fike D.A., Eisenman I., Hughes N.C., Tripati A.K., Fisher W.W. 2011. The magnitude and duration of late Ordovician-early Silurian glaciation. *Science*, **331**(6019): 903-906.

Fonseca V.M.M. 2001. *Brachiopoda (Stropheodontoidea, Chonetoidea e Delthyridioidea) do Devoniano Médio das Bacias do Amazonas e Parnaíba*. PhD Teses, Universidade do Rio de Janeiro, Rio de Janeiro, RJ. 167p.

Fonseca V.M.M. 2004. Chonetoidea (Brachiopoda) do Devoniano Médio das Bacias do Amazonas e Parnaíba, Brasil. *Arquivos do Museu Nacional*, **62**(2): 193-215.

Fonseca V.M.M. & Machado D. 2002. Some Devonian Chonetoidea (Brachiopoda) from the Amazon and Parnaíba Basins, Brazil, and their stratigraphic and paleogeographic implications. *Anais da Academia Brasileira de Ciências*, **74**: 362–363.

Fonseca V.M.M. & Ponciano L.C.M.O. 2011. Braquiópodes do Devoniano Médio das bacias do Amazonas e Parnaíba. In: Carvalho I.S. (Org.). *Paleontologia: Cenários de Vida*. Rio de Janeiro, Editora Interciência, p. 169-190.

Fonseca, V.M.M. & Costa D.M.M. 1999. Primeira ocorrência de Conulariida no Devoniano Médio da Bacia do Amazonas (Formação Maecuru), Estado do Pará, Brasil. *Boletim do Museu Nacional*, **48**: 1-11.

Gama J.M.J. 2008. *Braquiópodes da Formação Pimenteira (Devoniano Médio/Superior), na Região Sudoeste da Bacia do Parnaíba, Município de Palmas, Estado do Tocantins, Brasil*. MS Dissertation, Universidade de Brasília, Brasília. 64p.

Gonçalves M.A., Soares J.L., Santos H.P., Nogueira A.C.R. 2017. Traços fósseis dos depósitos marinhos rasos da Formação Pitinga, Siluriano Superior da Bacia do Amazonas, Rio Tapajós, Pará, Brasil. *Revista Brasileira de Paleontologia*, **20**(2): 179-194.

Gorjansky V.Y. & Popov L.E. 1985. The morphology, systematic position, and origin of inarticulate brachiopods with carbonate shells. *Paleontological Journal*, **3**:1-11.

Grahn Y. 2005. Silurian and Lower Devonian chitinozoan taxonomy and biostratigraphy of the Trombetas Group, Amazonas Basin, northern Brazil. *Bulletin of Geosciences*, **80**(4): 245-276.

Grahn Y. & Caputo M.V. 1992. Early Silurian glaciations in Brazil. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **99**: 9-15.

Grahn Y. & Melo J.H.G. 1990. *Bioestratigrafia dos quitinozoários do Grupo Trombetas nas faixas marginais da Bacia do Amazonas*. Petrobrás, Rio de Janeiro. p. 1-43. (Relatório Interno).

Grahn Y. & Melo J.H.G. 2004. Integrated Middle Devonian chitinozoan and miospore zonation of the Amazonas Basin, northern Brazil. *Revue de Micropaléontologie*, **47**(2): 71-85.

- Grahn Y. & Paris F. 1992. Age and correlation of the Trombetas Group, Amazonas Basin, Brazil. *Revue de Micropaléontologie*, **35**: 197-209.
- Holmer L.E. 2001. Phylogeny and classification: Linguliformea and Craniiformea. *The Paleontological Society Papers*, **7**: 11-26.
- Janvier P. & Melo J.H.G. 1988. Acanthodian fish remains from the Upper Silurian or Lower Devonian of the Amazon basin, Brazil. *Palaeontology*, **31**(3): 771-777.
- Johnson J.G. & Boucot A.J. 1973. Devonian brachiopods. In: Hallam A. (Ed). *Atlas of Palaeobiogeography*. Amsterdam, Elsevier, p. 89-96.
- Katzer F. 1897. Das Amazonas-Devon und seine Beziehungen zu den anderen Devon-gebieten der Erde. Verlag der Königl. *Böhmischen Gesellschaft der Wissenschaften*, **47**:1-50.
- Katzer F. 1903. *Grundzüge der geologie des unteren Amazonasgebietes (des Staates Pará in Brasilien)*. Verlag Von Max Weg, Leipzig. p. 1-298.
- Katzer F. 1933. Geologia do estado do Pará, (Brasil). *Boletim do Museu Paraense Emílio Goeldi de História Natural e Etnografia*, **9**: 1-269.
- Kauffman E.G. 1973. Cretaceous bivalves. *Atlas of Palaeobiogeography*, p.353-383.
- Kegel W. 1953. Contribuição para o estudo do Devoniano da bacia do Parnaíba, Brasil. *Boletim da Divisão de Geologia e Mineralogia*, **141**: 1-48.
- Klemme H.D. 1980. Petroleum basins – classification and characteristics. *Journal of Petroleum Geology*, **3**(2): 187-207.
- Kowalewski M., Simões M.G., Carrol M., Rodland D.L. 2002. Abundant brachiopods on a tropical, upwelling influenced shelf (Southeast Brazilian Bight, South Atlantic). *Paleios*, **17**: 277-286.
- Lange F.W. 1943. Novos fósseis devonianos do Paraná. *Arquivos Museu Paranaense*, **3**: 223-225.
- Lange F.W. 1967. Subdivisão bioestratigráfica e revisão da coluna siluro-devoniana da bacia do baixo Amazonas. In: Simpósio Sobre a Biota Amazônica. Belém. *Atas*, p. 215-326.
- Laurie J. 1987. The musculature and vascular system of two species of Cambrian Paterinida (Brachiopoda). *BMR Journal of Australian Geology and Geophysics*, **10**: 261-265.
- Loboziak S. & Melo J.H.G. 2002. Devonian miospore successions of Western Gondwana: update and correlation with Southern Euramerican miospore zones. *Review of Palaeobotany and Palynology*, **121**(2): 133-148.
- Loboziak S., Melo J.H.G., Matsuda N.S., Quadros L.P. 1997. Miospore biostratigraphy of the type Barreirinha formation (Curuá Group, Upper Devonian) in the Tapajós River Area, Amazon Basin, North Brazil. *Bull Centre Rech. Elf. Explor. Prod*, **21**(1): 187-205.
- Ludwig G. 1964. Divisão estratigráfico-faciológica do Paleozóico da Bacia Amazônica. Petrobras, *Ciência Técnica Petróleo, Seção: Exploração de petróleo*, **1**: 1-72.

Macambira E.M.B., Rezende N.G.A.M., Calderaro R.C.B., Assis N.P. 1977. *Projeto Sulfetos de Altamira/Itaituba*. Companhia de Pesquisa de Recursos Minerais – CPRM, Belém. p. 1-518. (Relatório interno).

Mateus S. 2017. A coleção de Braquiópodes do Museu de História Natural e da Ciência da Universidade do Porto. *Comunicações Geológicas*, **104**: 15-23.

Matsuda N.S., Winter W.R., Wanderley Filho J.R., Cacela A.S.M. 2010. O Paleozoico da borda sul da Bacia do Amazonas, Rio Tapajós – Estado do Pará. *Boletim de Geociências da Petrobrás*, **18**: 123-152.

Melo J.H.G. 1985. *A província Malvinocáfrica no Devoniano do Brasil: estado atual dos conhecimentos*. MS Dissertation, Universidade Federal do Rio de Janeiro, Rio de Janeiro. 890p.

Melo J.H.G. 1988. The Malvinokaffric realm in the Devonian of Brazil. In: McMillan N.J., Embry A.F., Glass D.J., (Eds.). *Devonian of the World, Volume III: Palaeontology, Palaeoecology and Biostratigraphy*. In: 2nd International Symposium on the Devonian System, Calgary. p. 667-703.

Melo J.H.G. & Loboziak S. 2003. Devonian – Early Carboniferous miospore biostratigraphy of the Amazon Basin, Northern Brazil. *Review of Palaeobotany and Palynology*, **124**: 131-202.

Nogueira A.C.R., Soares E.A.A., Truckenbrodt W. 1999. Contribuição ao paleoambiente e à paleogeografia da Formação Nhamundá (Siluriano inferior) na Bacia do Amazonas, região de Presidente Figueiredo – AM. In: 6^o Simpósio de Geologia da Amazônia, Manaus. *Boletim de resumos expandidos*, p. 399-402.

Penn-Clarke C.R. 2019. The Malvinokaffric Realm in the Early–Middle Devonian of South Africa. *Journal of African Earth Sciences*, **158**: 103549.

Penn-Clarke C.R. & Harper D.A.T. 2020. Early-Middle Devonian brachiopod provincialism and bioregionalization at high latitudes: A case study from southwestern Gondwana. *Geological Society of America Bulletin*, **133**(3-4): 819-836.

Penn-Clarke C.R., Rubidge B.S., Jinnah Z.A. 2018. Two hundred years of palaeontological discovery: review of research on the Early to Middle Devonian Bokkeveld Group (Cape Supergroup) of South Africa. *Journal of African Earth Sciences*, **137**: 157-178.

Ponciano L.C.M.O., Machado D.M.C., Souza A.R., Faria A.C.G., Vieira A.C.M. 2007b. Hábitos de vida da associação *Mucrospirifer katzeri* - *Ptychopteria eschwegei*, Formação Maecuru (Devoniano), Bacia do Amazonas, Brasil. In: Carvalho I.S. (Edt). *Paleontologia: Cenários de Vida*. Rio de Janeiro, Editora Interciência, p. 139-148.

Ponciano L.C.M.O., Machado D.M.C., Souza A.R., Faria A.C.G., Vieira A.C.M. 2007a. Hábitos de Vida da Associação “*Schuchertella*” *agassizi* – *Ptychopteria eschwegei*, Formação Maecuru, Devoniano, Bacia do Amazonas, Brasil. *Anuário do Instituto de Geociências - UFRJ*, **30**(1): 135-144.

Prothero D.R. 2013. Bringing fossils to life: An introduction to paleobiology. *Columbia University Press*, **3**: 1-1347

- Quadros L.P. 1985. *Distribuição bioestratigráfica dos Chitinozoa e Acritarchae na Bacia do Amazonas*. PhD Teses. Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ. 178p.
- Rathbun R. 1874. On the devonian Brachiopoda of Ererê, Province of Pará, Brazil. *Buffalo Society of Natural Sciences, Bulletin*, **1**: 236-261.
- Rathbun R. 1878. The Devonian Brachiopoda of the Province of Pará, Brazil. *Boston Society of Natural History*, **20**: 14-39.
- Rezende J.M.P. & Isaacson P.E. 2021. *Schellwienella clarkei* (Orthotetida, Brachiopoda): a new species from the Devonian of the Paraná Basin, Brazil. *Journal of Paleontology*, **95**(4): 733-747.
- Ribeiro V.R., Horodyski R.S., Sousa F.N., Comniskey J.C., Ghilardi R.P. 2024a. Linear morphometry and sclerochronology as paleoclimatic tools through Middle Devonian Kačák Event (Paraná Basin, Brazil). *Journal of South American Earth Sciences*, **134**: 104762.
- Ribeiro V.R., Nogueira C.S., Sedorko D., Sousa F.N., da Silva Caminha S.A.F., Ghilardi R.P. 2024b. Morphometric reduction in *Australocoelia palmata* associated with the Devonian marine transgression. *Journal of South American Earth Sciences*, **141**: 104947.
- Richter R. 1941. Devonische. In: Bubnoff S.V. (Ed.). Geologische Jahresberichte III. Band A. Historische und allgemeine Geologie. *Bericht über die Jahre 1938 und 1939*, p. 31-43.
- Richter R. & Richter E. 1942. Die Trilobiten der Weismes-Schichten am Hohen Venn, mit Bemerkungen über die Malvinocaffrische Provinz. *Senckenbergiana*, **25**: 156-179.
- Rocha P.F., Silveira R.R., Barbosa R.C.M. 2019. Age and palaeoenvironments of the Manacapuru Formation, Presidente Figueiredo (AM) region, Lochkovian of the Amazonas Basin. *Brazilian Journal of Geology*, **49**(4): 1-12.
- Romano P.S.R., Riff D., Oliveira D.R. 2007. Porque um “fóssil vivo” não pode existir: dedução lógica através de abordagem sistemática In: Carvalho I.S., Cassab R.C.T., Schwanke C., Carvalho M.A., Fernandes A.C.S., Rodrigues M.A.C., Carvalho M.S.S., Arai M., Oliveira. *Paleontologia: Cenários de Vida*. Rio de Janeiro, Editora Interciência, p. 51-59.
- Ross C.A. & Ross J.R.P. 1988. Late Paleozoic transgressive-regressive deposition. In: Wilgus C.K., Hastings B.S., Kendall C.G., Posamentier H.W., Ross C.A., Van Wagoner J.C. (Eds.). *Sea-Level Changes-Na Integrated Approach*. Tulsa, Society for Sedimentary Geology (SEPM) Special Publication, p. 227-247.
- Santos J.O.S., Hartmann L.A., Faria M.S.G., Riker S.R., Souza M.M., Almeida M.E., Mcnaughton N.J. 2006. A Compartimentação do Cráton em Províncias: avanços ocorridos no período de 2000-2006. In: 9º Simpósio de Geologia da Amazônia, Belém. *Anais [...]*, p. 156-159.
- Santos J.O.S., Hartmann L.A., Gaudette H.E., Groves D.I., Mcnaughton N.J., Fletcher I.R. 2000. A new understanding of the provinces of the Amazon Craton based on integration of field mapping and U-Pb and Sm-Nd geochronology. *Gondwana Research*, **3**(4): 453-488.
- Scheffler S.M., Fonseca V.M.M., Fernandes A.C.S. 2015. New crinoids from the Maecuru formation (Middle Eifelian; Amazon Basin, State of Pará, Brazil). *Geobios*, **48**: 57-69.

- Sharpe D. 1856. Description of Palaeozoic mollusca from South Africa. *Transactions of the Geological Society of London*, **2**(7): 206-215.
- Souza V.S. & Nogueira A.C.R. 2009. Manaus-Presidente Figueiredo (AM), borda norte da Bacia do Amazonas: um guia para excursão de campo. *Revista Brasileira de Geociências*, **39**(1): 16-29.
- Stemans P., Rubinstein C., Melo J.H.G. 2008. Siluro-Devonian miospore biostratigraphy of the Urubu River area, western Amazon Basin, northern Brazil. *Geobios*, **41**(2): 263-282.
- Tassinari C.C.G., Bettencourt, J.S., Geraldés M.C., Macambira M.J.B., Lafon J.M. 2000. The Amazonian cráton. In: Cordani U.G., Milani E.J., Thomaz Filho A., Campos D.A. *Tectonic Evolution of South America*. Rio de Janeiro, International Geologic Congress, p. 41-95.
- Tassinari C.C.G. & Macambira M.J.B. 1999. Geochronological provinces of the Amazonian Craton. *Episodes*, **22**(3): 174-182.
- Tassinari C.C.G. & Macambira M.J.B. 2004. A evolução tectônica do Cráton Amazônico. In: Mantesso-Neto V., Bartoreli A., Carneiro C.D.R., Brito-Neves B.B. (Eds.). *Geologia do Continente Sul-Americano: Evolução da Obra de Fernando Flávio Marques de Almeida*. São Paulo, Editora Beca, p. 471-485.
- Tassinari C.G.C. 1996. O mapa geocronológico do Cráton Amazônico no Brasil: revisão dos dados isotópicos. PhD Teses, Instituto de Geociências, Universidade de São Paulo, São Paulo, SP. 139p.
- Tomassi H.Z., Almeida C.M., Ferreira B.C., Brito M.B., Barberi M., Rodrigues G.C., Teixeira S.P., Capuzzo J.P., Gama-Júnior J.M., Santos M.G.K.G. 2015a. Preliminary results of paleontological salvage at Belo Monte Powerplant construction. *Brazilian Journal of Biology*, **75**(3): 277-289.
- Tomassi H.Z., Ferreira B.C., Almeida C.M., Barberi M., Brito M.B., Ramos L.S. 2015b. Relatório técnico Final do Programa de Salvamento do Patrimônio Paleontológico da Usina Hidrelétrica de Belo Monte. TERRAGRAPH Paleontologia. Belém. 1: 1-50.
- Torsvik T.H. & Cocks L.R.M. 2011. The Palaeozoic palaeogeography of central Gondwana. *Geological Society, London, Special Publication*, **357**(1): 137-166.
- Torsvik T.H. & Cocks L.R.M. 2013. New global palaeogeographical reconstructions for the early Palaeozoic and their generation. *Geological Society, London, Memoirs*, **38**(1): 5-24.
- Wanderley Filho J.R., Melo J.H.G., Fonseca V.M.M., Machado D.M.C. 2005. Bacias sedimentares brasileiras: Bacia do Amazonas. *Phoenix*, **7**(82): 1-6.
- Williams A., Brunton C.H.C., Carlson S.J. 1997. In: Kaesler R.L. (Ed.) *Treatise on Invertebrate Paleontology, Part H, Brachiopoda 1 (revised)*. Lawrence, Geological Society of America, p. 473-495.

Williams A., Brunton C.H.C., Carlson S.J., Alvarez F., Ansell A.D., Baker P.G., Bassett M.G., Blodgett R.B., Boucot A.J., Carter J.L., Cocks L.R.M., Cohen B.L., Copper P, Curry G.B., Cusack M., Dagys A.S., Emig C.C., Gawthrop A.B., Gourvennec R., Grant R.E.D., Harper A.T., Holmer L.E., Hong-fei H., James M.A., Yu-gan J., Johnson J.G., Laurie J.R., Lazarev S., Lee D.E., Lüter C., Sarah M., MacKinnon D.I., Manceñido M.O., Mergl M., Owen E.F., Peck L.S., Popov L.E., Racheboeuf P.R., Rhodes M.C., Richardson J.R., Jia-yu R., Rubel M., Savage N.M., Smirnova T.N., Dong-li S., Walton D., Wardlaw B., Wright A.D. 2000. *Treatise on invertebrate paleontology*. Part H. Brachiopoda (Revised 2), Linguliformea, Craniiformea, and Rhynchonelliformea (part). Kansas, Geological Society of America and University of Kansas Press, v 2, p.1-919.

Williams A., Brunton C.H.C., Carlson S.J., Alvarez F., Ansell A.D., Baker P.G., Bassett M.G., Blodgett R.B., Boucot A.J., Carter J.L., Cocks L.R.M., Cohen B.L., Copper P, Curry G.B., Cusack M., Dagys A.S., Emig C.C., Gawthrop A.B., Gourvennec R., Grant R.E.D., Harper A.T., Holmer L.E., Hong-fei H., James M.A., Yu-gan J., Johnson J.G., Laurie J.R., Lazarev S., Lee D.E., Lüter C., Sarah M., MacKinnon D.I., Manceñido M.O., Mergl M., Owen E.F., Peck L.S., Popov L.E., Racheboeuf P.R., Rhodes M.C., Richardson J.R., Jia-yu R., Rubel M., Savage N.M., Smirnova T.N., Dong-li S., Walton D., Wardlaw B., Wright A.D. 2007. *Treatise on invertebrate paleontology*. Part H. Brachiopoda (Revised 6), supplement. Kansas, Geological Society of America and University of Kansas Press, v 6, p.2321-3226.

Williams A., Brunton C.H.C., Carlson S.J., Alvarez F., Ansell A.D., Baker P.G., Bassett M.G., Blodgett R.B., Boucot A.J., Carter J.L., Cocks L.R.M., Cohen B.L., Copper P, Curry G.B., Cusack M., Dagys A.S., Emig C.C., Gawthrop A.B., Gourvennec R., Grant R.E.D., Harper A.T., Holmer L.E., Hong-fei H., James M.A., Yu-gan J., Johnson J.G., Laurie J.R., Lazarev S., Lee D.E., Lüter C., Sarah M., MacKinnon D.I., Manceñido M.O., Mergl M., Owen E.F., Peck L.S., Popov L.E., Racheboeuf P.R., Rhodes M.C., Richardson J.R., Jia-yu R., Rubel M., Savage N.M., Smirnova T.N., Dong-li S., Walton D., Wardlaw B., Wright A.D. 2002. *Treatise on invertebrate paleontology*. Part H. Brachiopoda (Revised 4), Rhynchonelliformea (part). Kansas, Geological Society of America and University of Kansas Press, v 4, p. 921-1688.

Williams A., Brunton C.H.C., Carlson S.J., Holme R.L.E., Popov L.E. 1996. A supra-ordinal classification of the Brachiopoda: Philosophical Transactions of the Royal Society of London. *Series B: Biological Sciences*, **351**: 1171-1193.

Williams A., Popov L.E., Holmer L.E., Cusack M. 1998. Diversity of paterinide brachiopods. *Palaeontology*, **41**: 221-262.

Zabini C. & Bosetti E.P. 2011. Paleoambientes revelados: lingulídeos como paleoindicadores em mares paleozoicos. In: Carvalho I.S., Srivastava N.K., Strohschoen O., Lana C.C. *Paleontologia: Cenários da Vida*. Rio de Janeiro, Editora Interciência, p. 289-299.

Zabini C., Bosetti E.P., Holz M. 2010. Taphonomy and taphofacies analysis of lingulids brachiopods from Devonian sequences of the Paraná Basin, Brazil. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **292**: 44-56.

Zabini C., Holz M., Bosetti E.P., Matsumura W.M.K., Horodyski R.S. 2012a. Sequence stratigraphy and taphonomic signatures of marine invertebrates: a Devonian (Pragian/Eifelian) example of the Paraná Basin. *Journal of south American Earth sciences*, **133**: 8-20.

Zabini C., Schiffbauer J.D., Xiao S., Kowalewski M. 2012b. Biomineralization, taphonomy, and diagenesis of Paleozoic lingulide brachiopod shells preserved in silicified mudstone concretions. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **326**: 118-127.

Zalán P.V. 1991. Influence of pre-Andean orogenies on the Paleozoic intracratonic basins of South America. *In: Simposio Bolivariano, Bogotá*. **1**(7): 17-29.

Zhang Z., Shu D., Han J., Liu J. 2005. Morpho-anatomical differences of the Early Cambrian Chengjiang and Recent lingulids and their implications. *Acta Zoologica*, **86**(4): 277-288.

**APÊNDICE A - MATERIAL SUPLEMENTAR DO CAPÍTULO 6,
SCHELLWIENELLA AMAZONENSIS NEW SPECIES (ORTHOTETIDA,
BRACHIOPODA): THE FIRST RECORD OF THE GENUS FROM THE DEVONIAN
OF THE AMAZONAS BASIN (MANACAPURU FORMATION – LOCHKOVIAN),
NORTH BRAZIL.**

Table 1. List of samples and measurements

(continues)

Ventral valve					
Catalog number	Collection number	Length mm	Width mm	Length / Width (L / W)	Ventral valve
MPEG-3761-I	C13P1-1.2A-I	Fragmented			External / contramold
MPEG-3762-Ia	C13P1-1.2B-I	9,6	11,7	0,82	Internal / mold
MPEG-3762-Ib	C13P1-1.2B-II	Fragmented			Internal / mold
MPEG-3762-Ic	C13P1-1.2B-III	7,6	9,6	0,79	Internal / mold
MPEG-3762-Id	C13P1-1.2B-IV	10,8	13,2	0,82	External / mold
MPEG-3763-I	C13P1-3.2	Fragmented			Internal / mold
MPEG-3764-I	C14P1-6.24A	Fragmented			Internal / mold
MPEG-3765-I	C3P1-1.9A	Fragmented			Internal / mold
MPEG-3766-I	C3P1-1.13B-II	Fragmented			External / mold
MPEG-3767-I	C3P1-1.29B	Fragmented			External / mold
MPEG-3768-Ia	C3P1-1.47D-I	8,8	12,5	0,70	Internal / mold
MPEG-3768-Ib	C3P1-1.47D-II	10,6	14,5	0,73	Internal / mold
MPEG-3769-Ia	C3P1-1.47F-I	6,6	9,4	0,70	External / contramold
MPEG-3770-I	C3P1-1.47K	12,3	16,3	0,75	Internal / contramold
MPEG-3771-I	C3P1-1.48B	7,6	9,7	0,78	External / contramold
MPEG-3772-I	C3P1-1.48C	7,8	10,9	0,72	External / contramold
MPEG-3773-I	C3P1-1.48F	Fragmented			Internal / mold
MPEG-3774-I	C3P1-1.50A	Fragmented			External / mold
MPEG-3775-Ia	C3P1-1.50B-I	Fragmented			Internal / mold
MPEG-3775-Ib	C3P1-1.50B-II	Fragmented			Internal / contramold
MPEG-3776-I	C3P1-1.52-I	Fragmented			External / contramold
MPEG-3777-I	C3P1-1.55	Fragmented			External / mold
MPEG-3778-I	C3P1-1.57	Fragmented			External / contramold
MPEG-3779-I	C3P1-1.59	Fragmented			Internal / mold
MPEG-3780-Ia	C3P1-1.63A-I	Fragmented			External / mold
MPEG-3781-Ia	C3P1-1.64B-I	11,8	15,7	0,75	Internal / mold

(continues)

Catalog number	Collection number	Length mm	Width mm	Length / Width (L / W)	Ventral valve
MPEG-3782-I	C3P1-1.67	12,8	16,5	0,78	External / mold
MPEG-3783-I	C3P1-1.69	Fragmented			Internal / contramold
MPEG-3784-I	C3P1-1.70A	Fragmented			Internal / mold
MPEG-3785-I	C3P1-1.70B	Fragmented			External / mold
MPEG-3786-I	C3P1-1.71B	15,1	18,7	0,81	Internal / contramold
MPEG-3787-Ia	C3P1-1.77A-III	Fragmented			External / mold
MPEG-3787-Ib	C3P1-1.77A-IV	Fragmented			External / mold
MPEG-3787-Ic	C3P1-1.77A-V	Fragmented			External / mold
MPEG-3787-Id	C3P1-1.77A-VI	Fragmented			Internal / mold
MPEG-3787-Ie	C3P1-1.77A-VIII	15,2	19,1	0,80	External / mold
MPEG-3788-I	C3P1-1.78	Fragmented			Internal / mold
MPEG-3789-I	C3P1-1.95	Fragmented			External / mold
MPEG-3790-I	C3P1-1.96	Fragmented			External / mold
MPEG-3791-I	C3P1-1.100	Fragmented			Internal / mold
MPEG-3792-I	C3P1-1.110	Fragmented			Internal / mold
MPEG-3793-Ia	C3P1-1.104-III	Fragmented			External / mold
MPEG-3794-Ia	C3P1-1.112-I	10,9	14,1	0,77	External / contramold
MPEG-3795-Ia	C3P1-1.113A-I	20,1	24,1	0,83	External / contramold
MPEG-3795-Ib	C3P1-1.113A-IV	12,1	15,6	0,78	External / mold
MPEG-3796-I	C3P1-1.113B	Fragmented			Internal / mold
MPEG-3797-I	C3P1-1.113C	Fragmented			External / contramold
MPEG-3798-Ia	C3P1-1.114-V	Fragmented			Internal / mold
MPEG-3798-Ib	C3P1-1.114-VI	11,5	14,4	0,80	External / contramold
MPEG-3798-Ic	C3P1-1.114-VII	Fragmented			External / contramold
MPEG-3798-Id	C3P1-1.114-VIII	9,4	12,1	0,78	Internal / mold
MPEG-3799-Ia	C3P1-1.124-I	Fragmented			External / mold
MPEG-3799-Ib	C3P1-1.124-II	Fragmented			Internal / mold
MPEG-3800-I	C3P1-1.126	Fragmented			External / mold
MPEG-3801-I	C3P1-1.129	Fragmented			External / mold
MPEG-3802-Ia	C3P1-1.135A-I	Fragmented			Internal / mold
MPEG-3802-Ib	C3P1-1.135A-II	Fragmented			External / mold
MPEG-3802-Ic	C3P1-1.135A-III	7,7	10,7	0,72	External / mold
MPEG-3803-Ia	C3P1-1.136A-III	Fragmented			Internal / mold
MPEG-3804-Ia	C3P1-1.137A-I	12,1	15,4	0,79	Internal / mold

(continues)

Catalog number	Collection number	Length mm	Width mm	Length / Width (L / W)	Ventral valve
MPEG-3804-Ib	C3P1-1.137A-II	Fragmented			Internal / mold
MPEG-3805-I	C3P1-1.137E	Fragmented			Internal / mold
MPEG-3806-I	C3P1-1.137J	Fragmented			Internal / mold
MPEG-3807-Ia	C3P1-1.140B-I	8,3	11,3	0,73	Internal / mold
MPEG-3807-Ib	C3P1-1.140B-II	Fragmented			Internal / mold
MPEG-3808-Ia	C3P1-1.141A-I	Fragmented			Internal / mold
MPEG-3808-Ib	C3P1-1.141A-II	10,4	14,4	0,72	Internal / mold
MPEG-3809-I	C3P1-1.141B	10,4	14,4	0,72	Internal / contramold
MPEG-3810-I	C3P1-1.142A	Fragmented			External / mold
MPEG-3811-I	C3P1-1.142C	Fragmented			External / mold
MPEG-3812-Ia	C3P1-1.143-I	4,7	6,9	0,68	Internal / mold
MPEG-3812-Ib	C3P1-1.143-II	Fragmented			Internal / mold
MPEG-3813-I	C3P1-1.144-I	Fragmented			Internal / mold
MPEG-3814-I	C3P1-1.148A	Fragmented			External / mold
MPEG-3815-I	C3P1-1.148B	Fragmented			External / contramold
MPEG-3816-Ia	C3P1-1.149A-I	Fragmented			Internal / contramold
MPEG-3816-Ib	C3P1-1.149A-II	11,9	16,3	0,73	Internal / contramold
MPEG-3817-Ia	C3P1-1.149B-I	Fragmented			Internal / mold
MPEG-3817-Ib	C3P1-1.149B-II	11,9	16,3	0,73	Internal / mold
MPEG-3817-Ic	C3P1-1.149B-III	8,5	12,7	0,67	Internal / mold
MPEG-3818-I	C3P1-1.151A	11,7	15,7	0,75	External / mold
MPEG-3819-I	C3P1-1.151B	11,7	15,7	0,75	Internal / mold
MPEG-3820-I	C3P1-1.159	Fragmented			Internal / mold
MPEG-3821-Ia	C3P1-1.161-I	Fragmented			Internal / mold
MPEG-3821-Ib	C3P1-1.161-II	9,6	13,2	0,73	Internal / mold
MPEG-3821-Ic	C3P1-1.161-III	Fragmented			Internal / mold
MPEG-3822-I	C3P1-1.164B	Fragmented			Internal / mold
MPEG-3823-Ia	C3P1-1.165C-II	Fragmented			Internal / mold
MPEG-3824-I	C3P1-1.166A	7,8	9,9	0,79	Internal / mold
MPEG-3825-I	C3P1-1.169	11,9	14,3	0,83	Internal / mold
MPEG-3826-I	C3P1-1.172	Fragmented			External / mold
MPEG-3827-Ia	C3P1-1.174A-III	Fragmented			External / mold
MPEG-3828-I	C3P1-1.176-I	Fragmented			Internal / mold
MPEG-3829-Ia	C3P1-1.177A-I	16,3	20,2	0,81	External / contramold

(continues)

Catalog number	Collection number	Length mm	Width mm	Length / Width (L / W)	Ventral valve
MPEG-3830-Ia	C3P1-1.178A-I	12,2	15,2	0,80	External / mold
MPEG-4157-Ia	C3P1-1.179A-I	Fragmented			Internal / mold
MPEG-4157-Ib	C3P1-1.179A-II	10,7	14,1	0,76	External / mold
MPEG-3831-Ia	C3P1-1.182-I	Fragmented			Internal / mold
MPEG-3831-Ib	C3P1-1.182-II	Fragmented			Internal / mold
MPEG-3832-I	C3P1-1.186	Fragmented			External / mold
MPEG-3833-I	C3P1-1.189A	11,8	14,9	0,79	External / mold
MPEG-3834-I	C3P1-1.189B	7,4	9,7	0,76	Internal / mold
MPEG-3835-I	C3P1-1.201	Fragmented			Internal / mold
MPEG-3836-I	C3P1-1.205	Fragmented			Internal / mold
MPEG-3837-Ia	C3P1-1.208B-I	Fragmented			Internal / mold
MPEG-3838-I	C3P1-4.4A	10,4	13,7	0,76	External / mold
MPEG-3686-Ib	C3P1-1.204	11,7	14,2	0,82	Internal / contramold
MPEG-4156-I	C3P1-1.47B	15,4	18,5	0,83	Internal / contramold
Catalog number	Collection number	Length mm	Width mm	Length / Width (L / W)	Dorsal valve
MPEG-3766-Ib	C3P1-1.13B-I	Fragmented			External / contramold
MPEG-3839-I	C3P1-1.31A	Fragmented			External / contramold
MPEG-3840-Ia	C3P1-1.47G-I	9,6	13,8	0,70	External / contramold
MPEG-3840-Ib	C3P1-1.47G-II	9,7	12,2	0,80	Internal / mold
MPEG-3841-I	C3P1-1.47H	7,8	11,5	0,68	Internal / mold
MPEG-3842-I	C3P1-1.47J	11,8	15,1	0,78	Internal / contramold
MPEG-3769-Ib	C3P1-1.47F-II	5,2	7,5	0,69	External / contramold
MPEG-3769-Ic	C3P1-1.47F-III	11,5	16,2	0,71	External / contramold
MPEG-3843-I	C3P1-1.48E	9,6	12,5	0,77	Internal / mold
MPEG-3844-I	C3P1-1.52-I	Fragmented			External / mold
MPEG-3845-I	C3P1-1.53	9,4	13,3	0,71	External / mold
MPEG-3780-Ib	C3P1-1.63A-II	9,6	12,8	0,75	External / contramold
MPEG-3780-Ic	C3P1-1.63A-III	Fragmented			External / mold
MPEG-3781-Ib	C3P1-1.64B-II	9,6	13,1	0,73	External / contramold
MPEG-3787-IF	C3P1-1.77A-I	10,2	12,4	0,82	External / contramold
MPEG-3787-IG	C3P1-1.77A-II	12,9	16,6	0,78	Internal / contramold
MPEG-3787-IH	C3P1-1.77A-IX	10,9	14,5	0,75	Internal / contramold
MPEG-3846-I	C3P1-1.82	10,4	14,7	0,71	External / contramold

(continues)

Catalog number	Collection number	Length mm	Width mm	Length / Width (L / W)	Dorsal valve
MPEG-3847-I	C3P1-1.89	Fragmented			External / contramold
MPEG-3848-I	C3P1-1.101	Fragmented			External / contramold
MPEG-3793-Ib	C3P1-1.104-I	7,3	10,4	0,70	Internal / contramold
MPEG-3793-Ic	C3P1-1.104-II	7,1	9,7	0,73	Internal / contramold
MPEG-3794-Ib	C3P1-1.112-II	9,9	12,6	0,79	External / contramold
MPEG-3795-Ic	C3P1-1.113A-II	11,3	14,6	0,77	External / mold
MPEG-3795-IId	C3P1-1.113A-III	11,3	14,6	0,77	External / contramold
MPEG-3849-I	C3P1-1.113D	Fragmented			External / contramold
MPEG-3850-I	C3P1-1.113E	Fragmented			External / contramold
MPEG-3798-Ie	C3P1-1.114-I	9,7	12,4	0,78	External / contramold
MPEG-3798-If	C3P1-1.114-III	7,3	10,1	0,72	Internal / mold
MPEG-3798-Ig	C3P1-1.114-IV	7,4	9,6	0,77	External / contramold
MPEG-3851-I	C3P1-1.117B	12,6	16,6	0,76	External / contramold
MPEG-3852-I	C3P1-1.120A	11,2	15,2	0,74	Internal / contramold
MPEG-3853-I	C3P1-1.120B	Fragmented			Internal / mold
MPEG-3854-I	C3P1-1.127A	Fragmented			Internal / mold
MPEG-3855-Ia	C3P1-1.130A-I	8,8	11,3	0,78	External / mold
MPEG-3855-Ib	C3P1-1.130A-II	12,7	15,3	0,83	External / mold
MPEG-3855-Ic	C3P1-1.130A-III	8,3	11,9	0,70	Internal / contramold
MPEG-3803-Ib	C3P1-1.136A-II	Fragmented			External / contramold
MPEG-3856-I	C3P1-1.137B	Fragmented			External / mold
MPEG-3857-I	C3P1-1.137F	Fragmented			External / contramold
MPEG-3807-Ib	C3P1-1.140B-II	Fragmented			Internal / mold
MPEG-3817-d	C3P1-1.149B-IV	5,9	8,7	0,68	External / contramold
MPEG-3858-I	C3P1-1.152A	Fragmented			External / mold
MPEG-3859-I	C3P1-1.152B	Fragmented			External / contramold
MPEG-3860-I	C3P1-1.154	7,4	9,6	0,77	External / mold
MPEG-3861-I	C3P1-1.155	11,1	14,4	0,77	External / contramold
MPEG-3862-I	C3P1-1.158	Fragmented			Internal / mold
MPEG-3863-I	C3P1-1.163	7,7	10,5	0,73	External / mold
MPEG-3823-Ib	C3P1-1.165C-I	8,6	12,3	0,70	External / contramold
MPEG-3864-I	C3P1-1.168	Fragmented			External / contramold
MPEG-3865-I	C3P1-1.173	9,9	13,1	0,76	External / contramold

(conclusion)

Catalog number	Collection number	Length mm	Width mm	Length / Width (L / W)	Dorsal valve
MPEG-3827-Ib	C3P1-1.174A-I	7,1	10,2	0,70	External / contramold
MPEG-3866-I	C3P1-1.175-I	Fragmented			Internal / mold
MPEG-3829-Ib	C3P1-1.177A-III	12,2	14,9	0,82	External / mold
MPEG-3829-Ic	C3P1-1.177A-IV	10,8	13,9	0,78	External / mold
MPEG-3830-Ib	C3P1-1.178A-II	Fragmented			External / contramold
MPEG-3867-I	C3P1-1.190	Fragmented			External / contramold
MPEG-3868-I	C3P1-1.191	Fragmented			External / contramold
MPEG-3869-I	C3P1-1.192A-II	Fragmented			External / mold
MPEG-3870-I	C3P1-1.193	Fragmented			External / mold
MPEG-3871-I	C3P1-1.198	Fragmented			External / mold
MPEG-3872-I	C3P1-1.200	Fragmented			External / contramold
MPEG-3837-Ib	C3P1-1.208b-II	Fragmented			External / contramold
MPEG-3873-Ia	C3P1-4.4B-I	Fragmented			Internal / mold
MPEG-3873-Ib	C3P1-4.4B-II	10,5	14,8	0,71	Internal / mold
MPEG-3874-I	C14P1-5.5	Fragmented			External / contramold
MPEG-3875-I	C14P1-6.12B	Fragmented			External / contramold
MPEG-3876-I	C14P1-6.14	Fragmented			External / contramold
MPEG-3877-I	C14P1-7.3	Fragmented			External / contramold
MPEG-3878-I	C13P1-1.17-I	Fragmented			Internal / mold

**ANEXO A - MATERIAL SUPLEMENTAR DO CAPÍTULO 7, RELATIONSHIPS
BETWEEN BRACHIOPOD FAUNA (LOCHKOVIAN–FRASNIAN) FROM
NORTHWEST GONDWANA (AMAZONAS BASIN) AND ENVIRONMENTAL
CHANGES DURING THE DEVONIAN.**

Table S1. Devonian brachiopods from the Amazonas Basin deposited in museum and university collections.

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-0001	<i>Chonostrophia knodi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0003	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0007	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0030	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0031	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0032	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0033	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0157	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0164	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0172	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0173	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0179	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0180	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0181	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0183	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0185	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-0034	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0170	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0178	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0212	<i>Mucrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0014	<i>Acrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0025	<i>Acrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0028	<i>Acrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0049	<i>Acrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0864	<i>Acrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0865	<i>Acrospirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0005	<i>Amphigenia elongata</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0175	<i>Amphigenia elongata</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0176	<i>Amphigenia elongata</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0018	<i>Schuchertella</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0026	<i>Schuchertella</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0053	<i>Schuchertella</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0024	<i>Schuchertella</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0029	<i>Schuchertella</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0019	<i>Plicoplasia curupira</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0037	<i>Plicoplasia curupira</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0041	<i>Plicoplasia curupira</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-0177	<i>Plicoplasia curupira</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0192	<i>Plicoplasia curupira</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0207	<i>Plicoplasia curupira</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0867	<i>Plicoplasia curupira</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0021	<i>Spirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0039	<i>Spirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0198	<i>Spirifer</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0190	<i>Spirifer derbyi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0023	<i>Chonetes freitasi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0051	<i>Chonetes freitasi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0174	<i>Chonetes freitasi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0184	<i>Chonetes freitasi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0204	<i>Chonetes freitasi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0209	<i>Chonetes freitasi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0035	<i>Leptocoelia</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0036	<i>Protoloptostrophia perplana</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0043	<i>Protoloptostrophia perplana</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0052	<i>Protoloptostrophia perplana</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0045	<i>Megastrophia hoeferi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0193	<i>Megastrophia hoeferi</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0047	<i>Rhipidomella musculosa</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-0187	<i>Rhipidomella musculosa</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0160	<i>Podolella derbyana</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0161	<i>Podolella derbyana</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0167	<i>Podolella derbyana</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0191	<i>Podolella derbyana</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0210	<i>Podolella derbyana</i>	Maecuru River / Monte Alegre - Pará	Maecuru Formation	João Coelho
MPEG-0008	<i>Schuchertella</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0158	<i>Schuchertella</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0159	<i>Schuchertella</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0214	<i>Schuchertella</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0830	<i>Schuchertella</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0027	<i>Derbynia jamesiana</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0213	<i>Pleurochonetes comstocki</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0825	<i>Chonetes onettianus</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0829	<i>Chonetes herbert-smithi</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0819	<i>Schizobulus truncatus</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation (possible Barreirimha Formation)	Frederich Katzer
MPEG-0827	<i>Schizobulus truncatus</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation (possible Barreirimha Formation)	Frederich Katzer
MPEG-0823	<i>Paranaia wardiana</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0826	<i>Paranaia wardiana</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0831	<i>Mucrospirifer</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-0828	<i>Mucrospirifer</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0822	<i>Plicoplasia curupira</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-0824	<i>Tropidoleptus carinatus</i>	Serra de Ererê / Monte Alegre - Pará	Ererê Formation	Frederich Katzer
MPEG-3655	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3656	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3657	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3658	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3659	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3660	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3661	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3662	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3663	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3664	<i>Orbiculoidea baini</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3665	<i>Orbiculoidea bodenbenderi</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3666	<i>Orbiculoidea bodenbenderi</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3667	<i>Orbiculoidea bodenbenderi</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3668	<i>Orbiculoidea bodenbenderi</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3669	<i>Orbiculoidea bodenbenderi</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3670	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3671	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3672	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-3673	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3674	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3675	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3676	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3677	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3678	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3679	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3680	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3681	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3682	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3683	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3684	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3685	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3686	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3687	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3688	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3689	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3680	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3691	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3692	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3693	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-3694	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3695	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3696	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3697	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3698	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3699	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3700	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3701	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3702	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3703	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3704	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3705	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3706	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3707	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3708	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3709	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3710	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3711	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3712	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3713	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3714	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-3715	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3716	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3717	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3718	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3719	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3720	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3721	<i>Orbiculoidea excentrica</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3722	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3723	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3724	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3725	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3726	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3727	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3728	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3729	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3730	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3731	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3732	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3733	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3734	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3735	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-3736	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3737	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3738	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3739	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3740	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3741	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3742	<i>Orbiculoidea xinguensis</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3743	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3744	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3745	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3746	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3747	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3748	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3749	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3750	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3751	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3752	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3753	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3754	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3755	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3756	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi

(continues)

Museum Paraense Emílio Goeldi				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
MPEG-3757	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3758	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3759	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
MPEG-3760	<i>Orbiculoidea katzeri</i>	Belo Monte / Vitória do Xingu - Pará	Manacapuru Formation	Henrique Tomassi
Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
002878-I	<i>Spirifer pedroanus</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002880-I	<i>Spirifer pedroanus</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
003642-I	<i>Spirifer pedroanus</i>	Erepecurú River	Manacapuru Formation	Not informed
001924-LE	<i>Spirifer pedroanus</i>	Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002923-I	<i>Spirifer pedroanus</i>	Teuapixuna waterfall, Maecuru River	Not informed	Annibal Alves Bastos; Pedro de Moura
002883-I	<i>Spirifer buarquianus</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002885-I	<i>Spirifer duodenarius</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002926-I	<i>Spirifer duodenarius</i>	Maecuru River	Maecuru Formation (Amazonas Basin)	Imperial Geological Commission of Brazil
002886-I	<i>Spirifer coelhoanus</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002887-I	<i>Spirifer coelhoanus</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002881-I	<i>Spirifer</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002884-I	<i>Spirifer</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002927-I	<i>Spirifer</i> sp.	Teuapixuna waterfall, Maecuru River	Not informed	Annibal Alves Bastos; Pedro de Moura
002879-I	<i>Mucrospirifer katzeri</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002882-I	<i>Mucrospirifer katzeri</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
002888-I	<i>Chonetes freitasi</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002889-I	<i>Chonetes freitasi</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002890-I	<i>Chonetes freitasi</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002891-I	<i>Chonetes freitasi</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002925-I	<i>Chonetes freitasi</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002893-I	<i>Amphigenia elongata</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002894-I	<i>Amphigenia elongata</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
003643-I	<i>Amphigenia elongata</i>	Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
000992-LE	<i>Amphigenia elongata</i>	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
002895-I	<i>Amphigenia</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002896-I	<i>Schuchertella agassizi</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002897-I	<i>Schuchertella agassizi</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002898-I	<i>Schuchertella</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002899-I	<i>Schuchertella</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
001925-LE	<i>Schuchertella</i>	Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002902-I	<i>Tropidoleptus carinatus</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002903-I	<i>Tropidoleptus carinatus</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
001922-LE	<i>Tropidoleptus carinatus</i>	Maecuru River	Maecuru Formation (Amazonas Basin)	Not informed
002900-I	<i>Montsenetes carolinae</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002924-I	<i>Montsenetes carolinae</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002901-I	<i>Strophomena hoeferi</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
002904-I	<i>Centronella jamesiana</i>	Teuapixuna waterfall, Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
000950-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000951-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000952-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000953-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000954-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000955-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000956-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000957-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000958-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000959-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000960-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000961-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000962-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000963-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000964-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000965-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000966-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000967-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000968-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000969-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
000970-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000972-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000973-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000974-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000976-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000977-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000978-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000979-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000980-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000981-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000982-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000983-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000984-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000985-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000986-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000987-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000988-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000990-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000991-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000993-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000994-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
000995-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000996-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000997-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
000998-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001000-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001001-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001002-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001003-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001005-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001006-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001009-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001010-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001011-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001012-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001013-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001015-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001016-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001017-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001018-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001019-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001020-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001021-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001023-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001024-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001025-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001026-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001027-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001028-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001029-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001030-LE	Brachiopoda	Not informed	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001031-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001033-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001034-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001035-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001036-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001037-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001038-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001039-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001040-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001041-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001042-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001043-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001044-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001045-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001046-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001047-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001048-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001049-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001050-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001051-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001052-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001053-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001054-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001055-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001056-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001057-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001058-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001059-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001060-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001061-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001062-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001063-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001064-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001065-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001066-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001067-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001068-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001069-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001070-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001071-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001072-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001073-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001074-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001075-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001076-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001077-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001078-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001079-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001080-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001082-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001084-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001085-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001086-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001087-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001088-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001089-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001090-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001091-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001093-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001094-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001095-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001096-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001097-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001099-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001101-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001102-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001104-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001106-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001107-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001108-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001109-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001110-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001111-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001112-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001113-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001114-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001116-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001118-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001119-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001120-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001122-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001125-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001126-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001127-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001130-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001131-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001132-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001133-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001134-LE	Brachiopoda	Maecuru River - Loc 94C	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001135-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001136-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001137-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001138-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001140-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001141-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001142-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001143-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001144-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001145-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001146-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001147-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001148-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001149-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001150-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001151-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001153-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001154-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001155-LE	Brachiopoda	Maecuru River - Loc 94C	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001156-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001157-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001159-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001160-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001161-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001162-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001163-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001164-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001165-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001166-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001167-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001168-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001169-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001170-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001171-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001172-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001173-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001174-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001175-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001176-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001177-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001178-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001179-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001180-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001181-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001182-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001184-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001185-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001186-LE	Brachiopoda	Maecuru River - Loc 92 (?) ou 91*?	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001188-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001189-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001190-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001191-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001194-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001198-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001199-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001200-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001201-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001202-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001203-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001204-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001205-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001206-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001207-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001208-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001209-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001210-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001211-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001212-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001213-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001214-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001215-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001216-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001217-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001218-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001219-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001220-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001221-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001222-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001223-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001224-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001225-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001226-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001227-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001228-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001230-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001231-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001232-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001233-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001234-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001235-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001236-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001237-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001238-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001239-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001240-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001241-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001242-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001243-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001244-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001246-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001248-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001249-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001250-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001251-LE	Brachiopoda	Maecuru River - Loc 91?	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001253-LE	Brachiopoda	Maecuru River - Loc 94	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001254-LE	Brachiopoda	Maecuru River - Loc 92	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001255-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001256-LE	Brachiopoda	Maecuru River - Loc 94A	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001257-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001258-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001259-LE	Brachiopoda	Maecuru River - Loc 94*	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001260-LE	Brachiopoda	Maecuru River - Loc 94B	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
001261-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001262-LE	Brachiopoda	Maecuru River - Loc 91	Maecuru Formation (Amazonas Basin)	Orville Adalbert Derby Expedition
001768-LE	Brachiopoda	Itauajuri	Maecuru Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
001920-LE	Brachiopoda	Maecuru River	Maecuru Formation (Amazonas Basin)	Annibal Alves Bastos; Pedro de Moura
002129-LE	Brachiopoda	Itauajuri	Maecuru Formation (Amazonas Basin)	Not informed
002130-LE	Brachiopoda	Itauajuri	Maecuru Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002131-LE	Brachiopoda	Itauajuri	Maecuru Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002816-I	<i>Chonetes comstockei</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002817-I	<i>Chonetes comstockei</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002818-I	<i>Chonetes comstockei</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002819-I	<i>Chonetes comstockei</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002820-I	<i>Chonetes comstockei</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002821-I	<i>Chonetes comstockei</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002822-I	<i>Chonetes comstockei</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002823-I	<i>Chonetes freitasi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002824-I	<i>Chonetes freitasi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002869-I	<i>Chonetes freitasi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Imperial Geological Commission of Brazil
002870-I	<i>Chonetes freitasi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Imperial Geological Commission of Brazil
002773-I	<i>Chonetes herbert-smithi</i>	Itauajuri	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002774-I	<i>Chonetes herbert-smithi</i>	Itauajuri	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002775-I	<i>Chonetes herbert-smithi</i>	Itauajuri	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
003484-I	<i>Chonetes herbert-smithi</i>	Itauajuri	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002868-I	<i>Chonetes onettianus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Imperial Geological Commission of Brazil
002858-I	<i>Chonetes</i> sp.	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
000336-I	<i>Schizobolus truncatus</i>	Serra de Ererê	Ererê Formation (possible Barreirimha Formation)	Francisco de Paula Oliveira
000337-I	<i>Schizobolus truncatus</i>	Serra de Ererê	Ererê Formation (possible Barreirimha Formation)	Francisco de Paula Oliveira
000338-I	<i>Schizobolus truncatus</i>	Serra de Ererê	Ererê Formation (possible Barreirimha Formation)	Francisco de Paula Oliveira
002776-I	<i>Schizobolus truncatus</i>	Itauajuri	Ererê Formation (possible Barreirimha Formation)	Mathias G. de Oliveira Roxo
002778-I	<i>Schuchertella agassizi</i>	Itauajuri	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002825-I	<i>Schuchertella agassizi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002826-I	<i>Schuchertella agassizi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002827-I	<i>Schuchertella agassizi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002828-I	<i>Schuchertella agassizi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002829-I	<i>Schuchertella agassizi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002830-I	<i>Schuchertella agassizi</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002831-I	<i>Spirifer pedroanus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002832-I	<i>Spirifer pedroanus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002833-I	<i>Spirifer pedroanus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002834-I	<i>Spirifer pedroanus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002835-I	<i>Spirifer pedroanus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo

(continues)

Museum de Ciências da Terra do Departamento Nacional de Produção - MCT/DNPM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
002839-I	<i>Spirifer pedroanus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002842-I	<i>Spirifer pedroanus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002779-I	<i>Mucrospirifer katzeri</i>	Itauajuri	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002840-I	<i>Retzia wardiana</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002841-I	<i>Retzia wardiana</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002844-I	<i>Orthis nettoana</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002845-I	<i>Orthis nettoana</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002847-I	<i>Rhynchonella dotis?</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002848-I	<i>Cyrtina curupira</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002849-I	<i>Tropidoleptus carinatus</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002850-I	Brachiopoda	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002853-I	<i>Terebratula derbyana</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002854-I	<i>Terebratula derbyana</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002856-I	<i>Derbyina</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002857-I	<i>Derbyina</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002777-I	<i>Orbiculoidea</i>	Itauajuri	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
002843-I	<i>Lingula</i>	Serra de Ererê	Ererê Formation (Amazonas Basin)	Mathias G. de Oliveira Roxo
National Museum of Natural History of the Smithsonian Institution - NMNH				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
USNM PAL 241088	<i>Tropidoleptus</i> sp.	State of Pará - Brazil	Ererê Formation (Amazonas Basin)	Unknown
USNM PAL 241089	<i>Tropidoleptus</i> sp.	State of Pará - Brazil	Ererê Formation (Amazonas Basin)	Unknown

(conclusion)

National Museum of Natural History of the Smithsonian Institution - NMNH				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
USNM PAL 241090	<i>Tropidoleptus</i> sp.	State of Pará - Brazil	Ererê Formation (Amazonas Basin)	Unknown
USNM PAL 241091	<i>Tropidoleptus</i> sp.	State of Pará - Brazil	Ererê Formation (Amazonas Basin)	Unknown
USNM PAL 24315 A	<i>Amphigenia</i> sp.	State of Pará - Brazil	Maecuru Formation (Amazonas Basin)	Unknown
USNM PAL 24315 B	<i>Amphigenia</i> sp.	State of Pará - Brazil	Maecuru Formation (Amazonas Basin)	Unknown
New York State Museum – NYSM				
Catalog Number	Taxon	Geographic location	Formation	Collectors (Aggregated)
NYSM 8657	<i>Strophomena hoeferi</i>	Not informed	Maecuru Formation	Not informed
NYSM 8658	<i>Strophomena hoeferi</i>	Not informed	Maecuru Formation	Not informed
NYSM 8176	<i>Derbyina jamesiana</i>	Not informed	Maecuru Formation	João Coelho
NYSM 8054	<i>Chonetes freitasi</i>	Not informed	Not informed	Not informed
NYSM 8055	<i>Chonetes freitasi</i>	Not informed	Not informed	Not informed
NYSM 2147	<i>Plicoplasia curupira</i>	Not informed	Ererê Formation	Not informed
NYSM 2148	<i>Plicoplasia curupira</i>	Not informed	Ererê Formation	Not informed
NYSM 8570	<i>Spirifer clarkei</i>	Not informed	Maecuru Formation	Not informed
NYSM 8571	<i>Spirifer coelhoanus</i>	Not informed	Maecuru Formation	Not informed
NYSM 8513	<i>Schizobolus truncatus</i>	Not informed	Possible Barreirimha Formation	Morgan Expedition
NYSM 8514	<i>Schizobolus truncatus</i>	Not informed	Possible Barreirimha Formation	Morgan Expedition
NYSM 8593	<i>Spirifer derby</i>	Not informed	Maecuru Formation	Not informed
NYSM 7972	<i>Spirifer lauro-sodreanus</i>	Not informed	Maecuru Formation	Morgan Expedition
NYSM 7999	<i>Spirifer pedroanus</i>	Not informed	Maecuru Formation	Morgan Expedition
NYSM 8000	<i>Spirifer pedroanus</i>	Not informed	Maecuru Formation	Morgan Expedition
NYSM 8001	<i>Spirifer pedroanus</i>	Not informed	Maecuru Formation	Morgan Expedition

Fonte: Corrêa & Ramos (2023).

Supplemental Material - Table S2. List of the Devonian brachiopods from the Amazonas Basin.

(continues)

Phylum Brachiopoda	Formations				Papers
	Manaca puru	Maecuru	Ererê	Barreirinha	
Class lingulata					
Order Lingulida					
<i>Orbiculoidea baini</i>	X				Corrêa & Ramos (2021)
<i>Orbiculoidea bodenbenderi</i>	X				
<i>Orbiculoidea excentrica</i>	X				
<i>Orbiculoidea xinguensis</i>	X				
<i>Orbiculoidea katzeri</i>	X				
<i>Orbiculoidea lodensis</i>				X	Rathbun (1878)
<i>Orbiculoidea</i> sp.			X		Fonseca & Ponciano (2011)
<i>Lingula erenensis</i>			X		Rathbun (1878)
<i>Lingula spatulata</i>			X		Rathbun (1878)
<i>Lingula graçana</i>				X	
<i>Lingula rodriguezii</i>				X	
<i>Lingula stauntoniana</i>				X	
<i>Lingula</i> sp.	X				Grahn & Melo (1990)
<i>Schizobolus truncatus</i>				X	Clarke (1913)
Class Rhynchonellata					
Order Orthida					
<i>Tropidoleptus carinatus</i>		X	X		Rathbun (1874)
<i>Discomyorthis hartti</i>		X			Carvalho (1975)
<i>Platyorthis nettoana</i>		X	X		
Order Terebratulida					
<i>Derbyina jamesiana</i>		X	X		Carvalho (1975)
<i>Paranaia wardiana</i>		X	X		
<i>Amphigenia elongata</i>		X			Rathbun (1878)
<i>Podolella rathbuni</i>		X			Copper (1977)
<i>Podolella derbyana</i>			X		Carvalho (1975)
Order Spiriferida					
<i>Acrospirifer duodenaria</i>		X			Carvalho (1975)
<i>Acrospirifer buarquianus</i>		X			
<i>Mucrospirifer katzeri</i>		X			Clarke (1913)
<i>Mucrospirifer pedroanus</i>		X	X		Carvalho (1975)
<i>Plicoplasia curupira</i>		X	X	X	



UNIVERSIDADE FEDERAL DO PARÁ
INSTITUTO DE GEOCIÊNCIAS
PROGRAMA DE PÓS-GRADUAÇÃO EM GEOLOGIA E GEOQUÍMICA



PARECER

Sobre a Defesa Pública da Tese de Doutorado de LUIZ FELIPE AQUINO CORRÊA

A banca examinadora da Tese de Doutorado de **LUIZ FELIPE AQUINO CORRÊA** orientando da Prof.^a Dr.^a Maria Inês Feijó Ramos (MPEG) e composta pelos professores doutores Carolina Zabini (UNICAMP), Renato Pirani Ghilardi (UNESP), Dermeval Aparecido do Carmo (UnB) e Joelson Lima Soares (UFPA) após apresentação da sua tese intitulada “**BRAQUIÓPODES DEVONIANOS DA BACIA DO AMAZONAS: NOVOS DADOS TAXONÔMICOS, PALEOBIOGEOGRÁFICOS E SUA RELAÇÃO COM AS MUDANÇAS AMBIENTAIS**”, emite o seguinte parecer:

O candidato realizou sua apresentação de forma clara, bem organizada e segura no tempo estipulado. Na arguição mostrou domínio da temática abordada e respondeu às perguntas formuladas pela banca. O trabalho escrito foi apresentado na forma de três artigos, sendo dois já publicados e um submetido a periódico internacional. Dessa forma, a tese atende às exigências protocolares do Programa de Pós-graduação em Geologia e Geoquímica para uma tese de doutorado.

Finalmente, a banca examinadora decidiu por unanimidade aprovar a **tese de doutorado com distinção**.

Belém, 01 de outubro de 2024

Documento assinado digitalmente

gov.br

MARIA INES FEIJO RAMOS

Data: 02/10/2024 09:50:02-0300

Verifique em <https://validar.iti.gov.br>

Prof.^a Dr.^a Maria Inês Feijó Ramos (Orientadora-MPEG)

Documento assinado digitalmente

gov.br

CAROLINA ZABINI

Data: 02/10/2024 10:48:17-0300

Verifique em <https://validar.iti.gov.br>

Prof.^a Dr.^a Carolina Zabini (UNICAMP)

Documento assinado digitalmente

gov.br

RENATO PIRANI GHILARDI

Data: 02/10/2024 12:57:33-0300

Verifique em <https://validar.iti.gov.br>

Prof. Dr. Renato Pirani Ghilardi (UNESP)

Prof. Dr. Dermeval Aparecido do Carmo (UnB)

Prof. Dr. Joelson Lima Soares (UFPA)

(conclusion)

Phylum Brachiopoda Class Rhynchonellata Order Spiriferida	Formations				Papers
	Manaca puru	Maecuru	Ererê	Barreirinha	
<i>Australospirifer? lauro-sodreanus</i>		X			Katzer (1903)
<i>Spirifer buarquianus</i>		X			Rathbun (1878)
<i>Spirifer derby</i>		X			
<i>Spirifer hartii</i>		X			
<i>Spirifer</i> sp.		X		X	Macambira <i>et al.</i> (1977); Melo (1985)
Order Spiriferinida					
<i>Cyrtina? maecuruensis</i>		X			Clarke (1899)
Order Rhynchonellida					
<i>Camartoechia? Aff. C. soppho</i>		X			Clarke (1913)
<i>Leptocoelia? sp</i>		X			Copper (1977)
<i>Rhynchonella ererensis</i>			X		Rathbun (1878)
Class Strophomenata					
Order Strophomenida					
<i>Protolptostrophia</i> sp.		X			Carvalho (1975)
<i>Megastrophia hoeferi</i>		X			Carvalho (1972)
Order Productida					
<i>Chonetes freitasi</i>		X	X		Rathbun (1878)
<i>Chonetes hebert-smithi</i>		X	X		Rathbun (1874)
<i>Chonetes? curuaensis</i>		X			Rathbun (1878)
<i>Chonetes onettianus</i>			X		Rathbun (1874)
<i>Montsenetes carolinae</i>		X			Fonseca (2004)
<i>Pleurochonetes comstocki</i>		X	X		
<i>Productella maecuruensis</i>		X			Rathbun (1878)
<i>Anoplia nucleata</i>		X			Katzer (1933)
<i>Chonostrophia knodi</i>		X			Copper (1977)
Order Orthotetida					
<i>Schuchertella agassizi</i>		X	X		Rathbun (1874)
<i>Orthotetes agassizi</i>				X	Macambira <i>et al.</i> (1977)

Fonte: Corrêa & Ramos (2023).



UNIVERSIDADE FEDERAL DO PARÁ
INSTITUTO DE GEOCIÊNCIAS
PROGRAMA DE PÓS-GRADUAÇÃO EM GEOLOGIA E GEOQUÍMICA



PARECER

Sobre a Defesa Pública da Tese de Doutorado de LUIZ FELIPE AQUINO CORRÊA

A banca examinadora da Tese de Doutorado de **LUIZ FELIPE AQUINO CORRÊA** orientando da Prof.^a Dr.^a Maria Inês Feijó Ramos (MPEG) e composta pelos professores doutores Carolina Zabini (UNICAMP), Renato Pirani Ghilardi (UNESP), Dermeval Aparecido do Carmo (UnB) e Joelson Lima Soares (UFPA) após apresentação da sua tese intitulada **“BRAQUIÓPODES DEVONIANOS DA BACIA DO AMAZONAS: NOVOS DADOS TAXONÔMICOS, PALEOBIOGEOGRÁFICOS E SUA RELAÇÃO COM AS MUDANÇAS AMBIENTAIS”**, emite o seguinte parecer:

O candidato realizou sua apresentação de forma clara, bem organizada e segura no tempo estipulado. Na arguição mostrou domínio da temática abordada e respondeu às perguntas formuladas pela banca. O trabalho escrito foi apresentado na forma de três artigos, sendo dois já publicados e um submetido a periódico internacional. Dessa forma, a tese atende às exigências protocolares do Programa de Pós-graduação em Geologia e Geoquímica para uma tese de doutorado.

Finalmente, a banca examinadora decidiu por unanimidade aprovar a **tese de doutorado com distinção**.

Documento assinado digitalmente
gov.br MARIA INES FEIJO RAMOS
Data: 02/10/2024 09:50:02-0300
Verifique em <https://validar.iti.gov.br>

Belém, 01 de outubro de 2024

Prof.^a Dr.^a Maria Inês Feijó Ramos (MPEG)

Documento assinado digitalmente
gov.br CAROLINA ZABINI
Data: 02/10/2024 10:48:17-0300
Verifique em <https://validar.iti.gov.br>

Prof.^a Dr.^a Carolina Zabini (Membro-UNICAMP)

Prof. Dr. Renato Pirani Ghilardi (UNESP)

Documento assinado digitalmente
gov.br RENATO PIRANI GHILARDI
Data: 02/10/2024 12:57:33-0300
Verifique em <https://validar.iti.gov.br>

Prof. Dr. Dermeval Aparecido do Carmo (UnB)

Documento assinado digitalmente
gov.br DERMEVAL APARECIDO DO CARMO
Data: 03/10/2024 12:44:19-0300
Verifique em <https://validar.iti.gov.br>

Prof. Dr. Joelson Lima Soares (Membro - UFPA)

Documento assinado digitalmente
gov.br JOELSON LIMA SOARES
Data: 03/10/2024 17:17:16-0300
Verifique em <https://validar.iti.gov.br>