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JOHNSON SARMENTO DE OLIVEIRA NASCIMENTO

PALEOECOLOGIA ISOTÓPICA, CRONOLOGIA E ASPECTOS TAXONÔMICOS DE VERTEBRADOS FÓSSEIS PRESENTES EM DEPÓSITOS CÁRSTICOS NO MUNICÍPIO DE PARIPIRANGA, NORDESTE DA BAHIA

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2024

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Tese apresentada ao Programa de Pós-Graduação em Geociências do Centro de Tecnologia e Geociências da Universidade Federal de Pernambuco, como requisito parcial para obtenção do título de Doutor em Geociências.
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Orientador: Prof. Dr. Edison Vicente Oliveira

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“Mas nós vibramos em outra frequência/Sabemos que não é bem assim/Se fosse fácil achar o caminho das pedras/ Tantas pedras no caminho não seria ruim” [...] (Gessinger, 2001).

RESUMO

As cavidades subterrâneas naturais podem constituir um local ideal para a preservação do registro fóssil. Nelas os restos orgânicos podem ficar protegidos dos fatores bióticos e abióticos, retardando a sua destruição antes do soterramento final. Entre as ocorrências de fósseis associados a cavidades naturais no Nordeste do Brasil, destaca-se a cidade de Paripiranga (Nordeste da Bahia), com grande riqueza paleontológica ainda pouco estudada. Na região de Paripiranga afloram rochas Neoproterozóicas da faixa de dobramento Sergipana, que incluem: mármores, metarritmitos, metapelitos, em parte calcíferos, e metacherts subordinados da Formação Olhos D'Água do Grupo Vaza-Barris, Supergrupo Canudos. O presente estudo teve como objetivo realizar a interpretação paleoecológica e paleoambiental do registro paleontológico encontrado em uma cavidade natural do Município de Paripiranga durante o Quaternário final. A caverna estudada é conhecida localmente como Furna do Cazuza, com entrada ampla e abundante aporte de sedimentos, além de uma grande quantidade de ocorrências de fósseis. Os espécimes coletados para a realização do presente estudo, são compostos por osteodermos de um indivíduo de Pampatheriidae, *Holmesina* sp., um abundante material ósseo de um indivíduo de Megatheriidae, *Eremotherium laurillardi*, e de um Scelidotheriidae, *Catonyx cuvieri*. Foram realizadas datações por radiocarbono (^{14}C) com espectrometria de massas com aceleradores (AMS) obtendo um intervalo de 36.6 a 7.6 mil anos cal BP, intimamente correlacionados com a megafauna do Pleistoceno-Holoceno. As análises isotópicas de δ^{13}C e δ^{18}O para as diferentes espécies, ajudaram a sugerir que esses táxons viviam em um habitat transicional entre florestas de baixa densidade e zonas transicionais de savana arbórea a aberta (δ^{13}C = -13,1‰ a 6,8‰), durante o Pleistoceno-Holoceno. Por fim foram levantadas informações do patrimônio paleontológico e espélico na região, e propostas estratégias para sua preservação.

Palavras-chave: Megafauna; taxonomia; cronologia; isótopos estáveis δ^{13}C, δ^{18}O; paleoecologia; Pleistoceno.

ABSTRACT

Natural underground cavities can constitute an ideal location for fossil record preservation. Within them, organic remains can be protected from biotic and abiotic factors, thereby delaying their destruction before final burial. Among occurrences of fossils associated with natural cavities in Northeast Brazil, Paripiranga stands out (Northeast of Bahia), with significant yet underexplored paleontological richness. In the Paripiranga region, Neoproterozoic rocks of the Sergipana folding belt outcrop, including marbles, metarhyolites, metapelites, partly calcareous, and subordinate metacherts of the Olhos D'Água Formation of the Vaza-Barris Group, Canudos Supergroup. This study aimed to conduct paleoecological and paleoenvironmental interpretation of the paleontological record found in a natural cavity in the Municipality of Paripiranga during the late Quaternary. The studied cave is locally known as Furna do Cazuza, with a wide entrance and abundant sediment input, along with a large number of fossil occurrences. Specimens collected for this study consist of osteoderms from an individual of Pampatheriidae, *Holmesina* sp., abundant bone material from an individual of Megatheriidae, *Eremotherium laurillardi,* and a Scelidotheriidae, *Catonyx cuvieri*. Radiocarbon dating (^{14}C) was performed using Accelerator Mass Spectrometry (AMS), yielding a range of 36.6 to 7.6 thousand calibrated years BP, closely correlated with the Pleistocene-Holocene megafauna. Isotopic analyses of $\delta^{13}C$ and $\delta^{18}O$ for the different species helped suggest that these taxa inhabited a transitional habitat between low-density forests and transitional zones from arborealto open savannah ($\delta^{13}C$ = -13.1‰ to 6.8‰) during the Pleistocene-Holocene. Finally, information on paleontological and speleological heritage in the region was gathered, and preservation strategies were proposed.

Keywords: Megafauna; taxonomy; chronology; stable isotopes δ13C, δ18O; paleoecology; Pleistocene.

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1 INTRODUÇÃO

As cavidades subterrâneas naturais podem constituir um local ideal para a formação de janelas temporais, nelas os restos orgânicos podem ficar protegidos dos fatores bióticos e abióticos, retardando a sua destruição antes do soterramento final (e.g. Bergqvist e Almeida 2004). As cavernas da Região Intertropical Brasileira (RIB) abrigam importantes depósitos fossilíferos de vertebrados terrestres, cujo conteúdo fóssil é taxonomicamente bem conhecido (e.g. Cartelle, 1992; Trifilio *et al*., 2022). Tais regiões cársticas de ambientes fechados, são bem diferentes da superfície terrestre (Andrews, 1990), entretanto representam alguns dos maiores depósitos fossilíferos de vertebrados terrestres (e.g. Cartelle, 1992; 1999) no Brasil.

O município de Paripiranga, Bahia, localizada na região nordeste do país, está inserida em uma região cárstica denominada Supergrupo Canudos (Pereira *et al*., 2017), e apesar de rica em ocorrência de cavidades naturais, apresenta poucos trabalhos aprofundados voltados à paleontologia (Lima, 2017; Nascimento *et al*., 2020). A Geologia da área de estudo apresenta afloramento de rochas Neoproterozóicas da faixa de dobramento Sergipana, que incluem: mármores, metarritmitos, metapelitos, em parte calcíferos, e metacherts subordinados da Formação Olhos D’Água do Grupo Vaza-Barris (Pereira *et al*., 2017).

O município é conhecido por apresentar uma geologia rica em rocha calcário, sendo de grande interesse econômico na região, decorrente de suas múltiplas utilidades, incluindo a fabricação de cimento e cal, bem como seu papel como corretivo para solos ácidos, sendo amplamente utilizado na agricultura (Lino, 2001). De acordo com o laudo emitido no estudo realizado por Cimar (2014), o calcário da região apresentou alta qualidade para utilização. Nos últimos anos tramita o processo de instalação/operação de uma fábrica de extração de calcário na região – a *Cimentos da Bahia*.

O material analisado no presente estudo corresponde a fósseis de vertebrados coletados nas cavernas de Paripiranga, em especial na Furna do Cazuza, que se trata de uma cavidade com um abismo como entrada, característico de uma armadilha natural. Os restos (dentes, ossos e osteodermos) coletados correspondem a espécies de mamíferos fósseis que viveram durante o Pleistoceno. Adicionalmente aos dados resultantes da caverna Furna do Cazuza, foram ainda utilizados dados cronológicos e isotópicos (δ^{13}C e δ^{18}O) de representantes da fauna pleistocênica de outras duas cavidades na região, Gruta do Bom Pastor e Caverna das Borboletas para compor mais dados para melhor entender o paleoambiente.

A tese foi organizada em três artigos. O primeiro descreve os espécimes coletados de *Catonyx cuvieri*, *Eremotherium laurillardi* e *Holmesina* sp., registrando nova ocorrência para *Eremotherium laurillardi* e *Holmesina* sp. e uma descrição dos restos de *C. cuvieri*, sendo a espécie mais completa entre os representantes da megafauna encontrados no município de Paripiranga até o momento, e por fim faz uma breve inferência paleoambiental. O segundo artigo realiza a interpretação paleoecológica e paleoambiental com base nos dados obtidos de datação AMS ^{14}C e das análises isotópicas de δ^{13}C e δ^{18}O do município de Paripiranga durante o Quaternário final, atribuindo dieta, habitat e reconstituição paleoambiental para as espécies *Holmesina* sp., *C. cuvieri, Palaeolama major, Toxodon platensis* e um pequeno mamífero indeterminado. O terceiro artigo trata da riqueza e diversidade espeleológica e fossilífera das cavidades naturais de Paripiranga, apontando o potencial para a educação patrimonial e criação de espaços de memória, no município, à luz de buscar uma proteção do material fossilífero e das cavidades devido aos impactos diretos e indiretos causados pelo projeto de implantação de uma fábrica de cimento na região.

1.1 PALEONTOLOGIA: MAMÍFEROS DO PLEISTOCENO NO BRASIL

O Período Pleistoceno é situado na escala cronoestratigráfica entre o Plioceno e o Holoceno, tendo início há aproximadamente 2,6 milhões de anos e estima-se que durou até 11,5 mil anos (Head e Gibbard, 2015). Ao tratar sobre a fauna de vertebrados que viveram durante esse período torna-se imprescindível citar sobre alguns eventos relacionados a sua diferenciação e migração do mamíferos. De maneira geral, a geografia tem grande influência sobre a biota, levando-a a migrar ou ser isolada parcial ou totalmente por barreiras ou semi-barreiras naturais (e.g. desertos, montanhas, rios, grandes corpos d'água), o que pode acarretar processos de diferenciação entre espécies, famílias e grupos (Simpson, 1940).

Entre as diferentes barreiras geográficas, a própria disposição dos continentes ao longo das eras está intimamente relacionada à migração dos mamíferos entre as Américas (Vaughan *et al*., 2000). Ressaltamos ainda a ocorrência de um dos mais importantes eventos atrelado a história dos mamíferos no continente americano, o Grande Intercâmbio Biótico Americano (GIBA, "*Great American Biotic Interchange*" em inglês, GABI – Webb, 1985; Woodburne, 2010). Durante o evento, ocorreu o forte fluxo de intercâmbio entre as faunas da América do Norte e América do Sul, com os animais que migraram do Norte para Sul apresentando mais sucesso no processo de propagação e diferenciação (Webb, 1976; 1985; 1991). A própria variabilidade, diferenciação e abundância desses animais na América do Sul está evidenciada nos fósseis registrados nos diferentes tipos de depósitos sedimentares como, os tanques naturais, lagoas, rios e cavernas (Cartelle, 1994; Cione *et al*., 2007; Paula Couto, 1953; 1979).

Os mamíferos de porte avantajado que viveram durante o Pleistoceno receberam a denominação genérica de megafauna (Paula Couto, 1979), tendo representantes com massa corpórea acima de uma tonelada, incluindo os mastodontes (e.g. *Notiomastodon platensis* ~6.000 kg), preguiças gigantes (e.g. *Eremotherium laurillardi* ~2.200 kg; *Ocnotherium gigantum* ~1.300 kg), toxodontes (e.g. ~2.200 kg), e gliptodontes, alguns vindos da América do Norte (Paula Couto, 1953; 1979; Dantas, 2022; Barbosa *et al*., 2023). De acordo com alguns trabalhos mais recentes, outros animais de porte inferior são considerados como "pertencentes" a megafauna, pois apresentam ocorrência no mesmo período, ambientes e exibindo interações intra- e interespecíficas (e.g. França, *et al*., 2015; Barbosa *et al*., 2023), dessa maneira consideramos aqui, "megafauna" os mamíferos entre 40 e 6000 kg que viveram entre o mesmo período, registrados nos diversos estudos aqui levantados (Oliveira et al., 2013; Asakura et al., 2016; Oliveira *et al*., 2017; Nascimento *et al*., 2020).

Em aspecto de cenário nacional, a megafauna pleistocênica habitou mais intensamente a área zoogeográfica denominada por Cartelle (1999) como Região Intertropical Brasileira – RIB, essa classificação baseou-se nos achados de mamíferos de grande porte em diferentes sítios paleontológicos (e.g. lagoas, tanques naturais, cavernas), e que esses animais coexistiram na mesma faixa cronológica, no Pleistoceno Final entre 20 e 10 mil anos, listando a ocorrência nos estados do Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia, Espírito Santo, Rio de Janeiro, Goiás. Posteriormente é sugerido a adição dos estados do Mato Grosso do Sul e São Paulo (Oliveira *et al.*, 2017).

As pesquisas paleontológicas que cunham sobre a Paleomastozoologia em território nacional, em sua grande maioria tratam dos aspectos anatômicos e taxonômicos dos fósseis coletados no Brasil, com destaque para as grandes contribuições como Paula Couto (1979) e Cartelle (1992; 1999). Apesar de ainda haver uma certa predominância de estudos anatômicos e taxonômicos de mamíferos fósseis, nas últimas décadas têm surgido abordagens que exploram outros aspectos, como tafonomia, cronologia, biogeografia, paleoecologia e paleoclimatologia (Carvalho, 2010; Lobo *et al*., 2015; Mayer *et al*., 2016; Andrade *et al*., 2023; Alves-Silva *et al*., 2023; Jacob *et al*., 2024).

1.3.1 CAVIDADES NATURAIS E TRABALHOS PALEONTOLÓGICOS NO MUNICÍPIO DE PARIPIRANGA/BA

Cavidades subterrâneas podem ser formadas através de processos de dissolução das rochas, geralmente carbonáticas, por fluxos de água subterrânea (Piló, 2000). Estes ambientes propícios à formação de cavernas são denominados cársticos, neles, as rochas vão sendo dissolvidas e esculpidas pelo fluxo contínuo de água, ao longo de milhares de anos (Jansen *et al*., 2012). Fluxos aquosos carregando sedimentos, podem auxiliar no processo de transporte de restos orgânicos para o interior dessas cavidades, e contribuindo para a fossilização da fauna que habitava nas proximidades (Auler *et al*., 2005).

O território brasileiro é abundantemente dotado de cavidades em rochas calcárias naturais. De acordo com o último levantamento disponibilizado pelo Centro Nacional de Pesquisa e Conservação de Cavernas do Instituto Chico Mendes de Conservação da Biodiversidade (CECAV/ICMBio), há 23.378 registros no Brasil (CECAV, 2022). O estado de Minas Gerais lidera com 10.570 cavernas (46,72%), seguido pelo Pará, com 2.858 (12,63%), pela Bahia, com 1.694 (7,49%) e pelo Rio Grande do Norte, com 1.362 cavernas (6,02%). O relatório também apresenta uma análise cruzada dos dados das classes de rochas com as áreas de ocorrência de cavernas no Brasil. Nesse sentido, observa-se que a categoria das rochas carbonáticas é a que detém o maior número de cavernas, correspondendo a 12.267 (52%) da base de dados.

Já segundo o Cadastro Nacional de Cavernas do Brasil (CNC-SBE, 2023), 953 cavernas estão cadastradas para o estado da Bahia, sendo 81 para o município de Paripiranga. Conforme o CNC-SBE (2023), Paripiranga ocupa o vigésimo primeiro lugar em nível nacional e o décimo quarto lugar em nível estadual, na Bahia, como o município com o maior número de cavidades naturais. As cavernas quando sobrepostas ao mapa de potencialidade de ocorrências de cavidades, se localizam em áreas de alta potencialidade, geralmente associadas aos metacalcários do Supergrupo Canudos (Jansen, *et al*., 2012; Santana *et. Al*., 2013).

As cavidades naturais são consideradas entre os depósitos fossilíferos mais significativos do país, com uma representação abundante de acumulações fósseis de mamíferos quaternários, especialmente na Região Intertropical Brasileira (Cartelle, 1999; ampliada por Oliveira *et al*., 2017). Esta região é caracterizada por uma ampla variedade de ambientes vegetacionais, que vão desde cerrados até áreas mais abertas (Lessa *et al*., 2021; França *et al*., 2023). O estado da Bahia possui diversas cavidades naturais, com dimensões e características distintas, como apresentado acima, além de inúmeros sítios paleontológicos (Leoni e Silva, 2018).

Numerosos fósseis de vertebrados já foram registrados em cavernas do território brasileiro, nas regiões Sudeste (e.g. Hubbe *et al*., 2011), Centro-Oeste (e.g. Oliveira *et al*., 2017; 2020) e Nordeste (e.g. Araújo-Júnior e Porpino, 2011; Castro *et al*., 2014; Nascimento *et al*., 2020). O registro de paleovertebrados em diferentes regiões da Bahia mostra uma grande variedade de táxons de mamíferos, incluindo Pilosa, Carnivora, Cingulata, Proboscidea, Notoungulata, Perissodactyla, Certartiodactyla, Litopterna, Rodentia, Didelphimorphia e Chiroptera (Cartelle, 1992; 1999; Scherer *et al*., 2017; Silva *et al*., 2019; Eltink *et al*., 2020; Greco *et al*., 2022).

1.2.1 Fósseis em Paripiranga, Nordeste da Bahia

Desde o ano de 2001, atividades de campo, trabalhos técnicos de prospecção e coleta de vertebrados fósseis do Quaternário, tem se intensificado graças à cooperação entre paleontólogos do Laboratórios Integrados de Paleontologia e Espeleologia do Setor de Paleontologia do Museu de História Natural da Universidade Federal de Alagoas (LIPE-SP-MHN-UFAL) e membros do Grupo Mundo Subterrâneo de Espeleologia (GSME – Bahia) nas cavernas de Paripiranga, Bahia. Inicialmente as pesquisas tratavam apenas de estudos preliminares sobre a paleofauna que habitava a região (Dantas, 2005; Dantas *et al*., 2010; Donato *et al*., 2008; Silva *et al*., 2012).

Dantas (2005), apresenta um resumo onde foi realizada a identificação de uma falange distal (LPUFS 2187) de fóssil de mamífero, coletado em uma cavidade subterrânea (não informada), localizada no povoado de Roça Nova, cidade de Paripiranga, nordeste do estado da Bahia, depositada no acervo do Laboratório de Paleontologia da Universidade Federal de Sergipe (LPUFS). O espécime foi atribuído previamente a uma preguiça gigante da espécie *Catonyx cuvieri*. No entanto, apenas um elemento esqueletal (falange distal) talvez não seja suficiente para uma identificação precisa a nível de espécie, mantendo assim uma provável identificação mais ampla como família Scelidotheriidae Ameghino, 1889.

Após alguns anos, Dantas *et al*., (2010) registraram novos achados de mamíferos pleistocênicos para a cavidade Gruta do Bom Pastor, localizada também na Roça Nova, Paripiranga, Bahia. Foram identificados fragmentos de dentes (LPUFS 4692) que foram atribuídos a Toxodontinae e falange média do dígito II da mão (LPUFS 4694) e vértebra caudal

(LPUFS 4693) atribuídas a um Mylodontinae. Ainda para a mesma cavidade é documentada a ocorrência de fósseis de morcego pertencente ao gênero *Myotis* sp. (Donato *et al*., 2008).

Em outra cavidade natural na região, denominada Furna do Fim do Morro do Parafuso, também conhecida localmente como Caverna dos Caramujos, situada no povoado do Corredor Vermelho, foi documentada, por meio de uma breve publicação em formato de resumo, a presença de fósseis de *Pecari tajacu = Dycotiles tajacu*. Estes incluem fragmentos do crânio, corpo de vértebra, ramo mandibular direito e esquerdo articulados, com alguns dentes ainda implantados nos alvéolos e outros isolados (Silva *et al*., 2012).

Nos últimos anos as atividades de pesquisa realizadas pelo LIPE na região foram intensificadas e obtiveram novos resultados sobre os processos tafonômicos e sedimentológicos que ocorreram aos restos esqueletais fossilizados (Lima, 2017; Nascimento, 2018). Os resultados da pesquisa conduzida por Lima (2017) em uma das cavidades da região (Gruta da Presa I), mostraram que os achados são recentes e caracterizados por uma escassa diversidade de mamíferos, exibindo uma datação de 560 anos AP (+/-20) para *Dycotiles tajacu*, espécie com predominância de ossos.

Os estudos realizados por Nascimento *et al*. (2020) na Caverna das Borboletas, no município de Paripiranga categoriza a cavidade como a mais rica em biodiversidade paleontológica de mamíferos do município, sendo o primeiro trabalho a efetuar as primeiras correlações e inferências sobre a paleoecologia desses animais durante o final do Pleistoceno-Holoceno. Nesse estudo foi constatada a presença de elementos cranianos e pós-cranianos de seis espécies distribuídas em dez famílias: *Palaeolama major* (Camelidae), *Mazama gouazoubira* (Cervidae), *Toxodon platenses* (Toxodontidae), *Smilodon populator* (Felidae), *Coendou* sp. (Erethizontidae), *Hippidion principale* (Equidae), Tayassuidae, Glyptodontidae, Tapiridae, Erethizontidae, Testudines.

1.3.2 OBJETIVOS

1.3.3 Objetivo Geral

Propor uma reconstrução paleoecológica e paleoambiental do município de Paripiranga (Nordeste da Bahia) durante o Quaternário final.

1.3.4 Objetivos Específicos

- Prospectar a cavidade natural Furna do Cazuza (Abismo) localizada em uma zona de drenagem no município de Paripiranga; diagnosticando as feições cársticas;
- Identificar a nível taxonômico mais baixo, salvaguardar, descrever e analisar os espécimes fósseis coletados;
- Realizar datações e análises isotópicas de fósseis provenientes das cavidades naturais da região;
- Comparar com os modelos paleoambientais já propostos para a região nordeste da Bahia;
- Elaborar propostas para proteção do patrimônio paleontológico e espeleológico do município de Paripiranga.

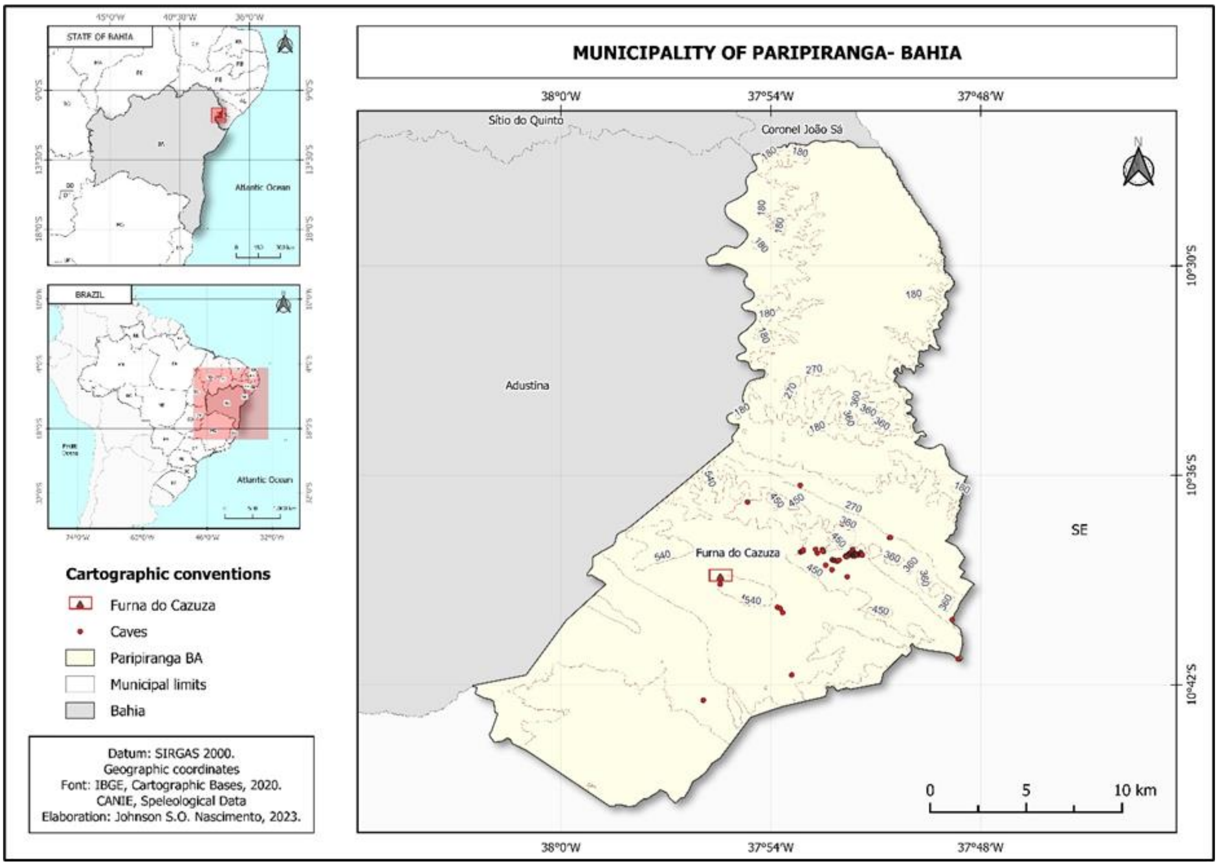
2 CARACTERIZAÇÃO DA ÁREA DE ESTUDO

Nessa seção será apresentada a caracterização da área de estudo englobando o georreferenciamento, Geologia e Geomorfologia, vegetação, clima e recursos hídricos da região de interesse.

2.1 GEORREFERENCIAMENTO

O município de Paripiranga (Altitude 430 metros; 10°41’00” S, 37°51’00” O) está situado na região Nordeste do Estado da Bahia, limitando-se a leste e sul com o Estado de Sergipe, a oeste com o município de Adustina (BA) e a norte com o município de Coronel João Sá (BA) (Figura 1).

Figura 1 – Mapa de localização das cavidades naturais no município de Paripiranga, Bahia

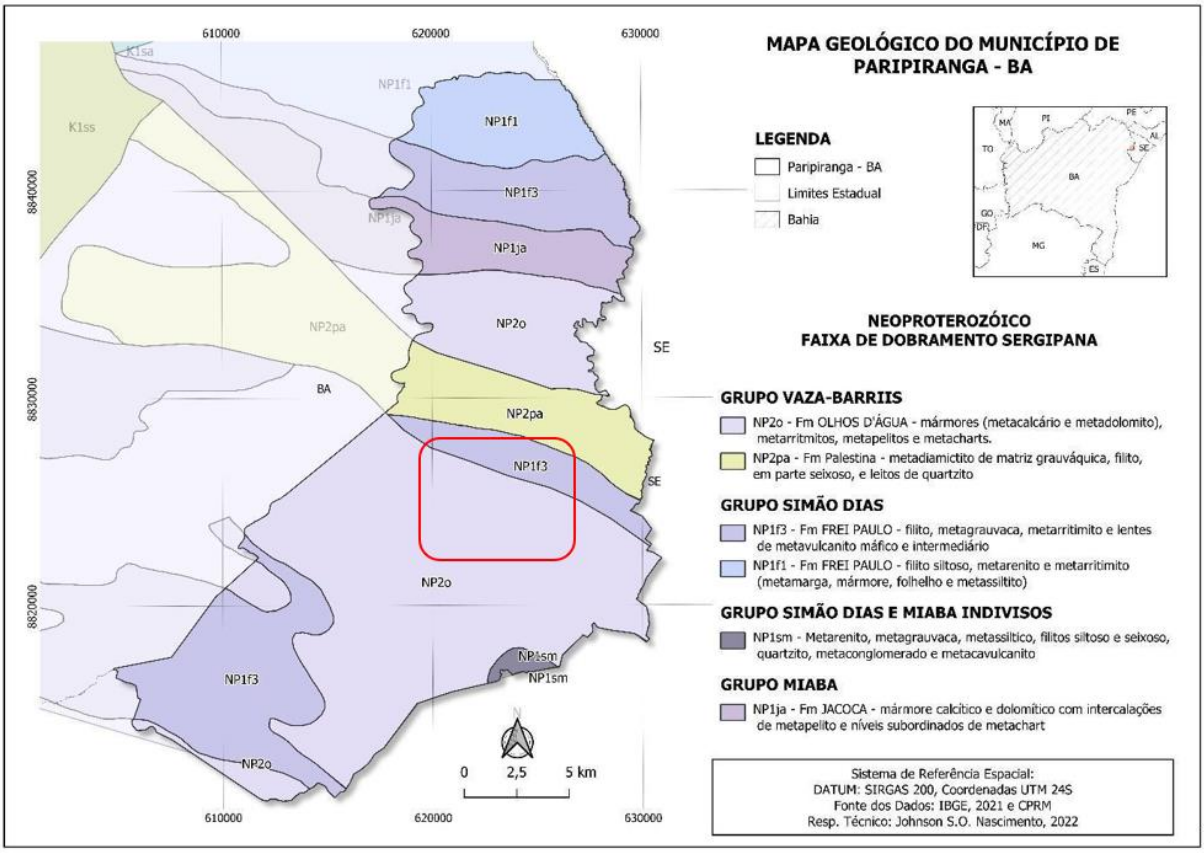


Fonte: O autor (2024).

2.2 GEOLOGIA E GEOMORFOLOGIA

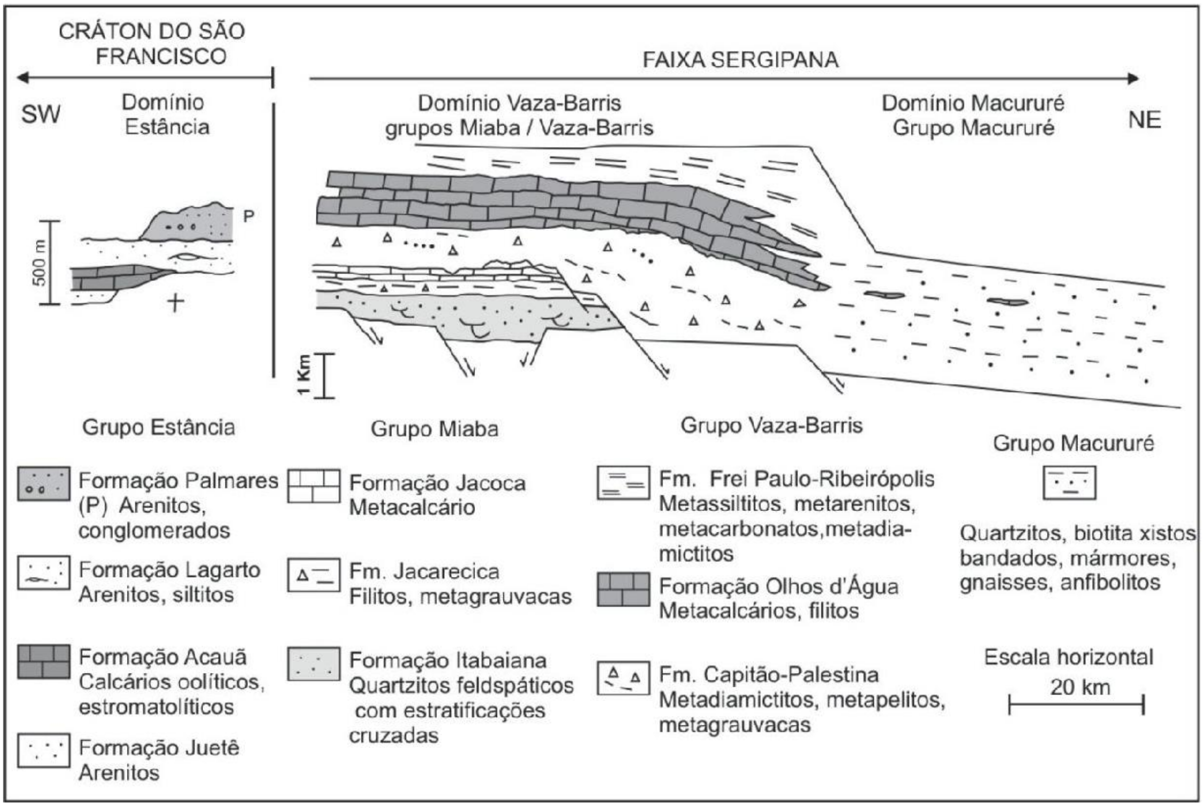
Na área de estudo, afloram rochas Neoproterozóicas da faixa de dobramentos Sergipana (Figura 2), que incluem: metacalcários, metadolomitos, intercalações de metapelitos e níveis subordinados de metacherts da Formação Jacoca do Grupo Miaba; além de metarenitos, metagrauvacas, filitos siltosos, filitos seixosos e quartzitos dos Grupos Simão Dias e Miaba (Indivisos); filitos, metarenitos, metarritmitos e metagrauvacas, da Formação Frei Paulo do Grupo Simão Dias; metadiamictitos de matriz grauváquica, filitos, em parte seixoso e lentes de quartzito da Formação Palestina, e mármores, metarritmitos, metapelitos, em parte calcíferos, e metacherts subordinados da Formação Olhos D'Água do Grupo Vaza-Barris (Pereira *et al*. 2017) (Figura 3).

Figura 2 – Mapa geológico com as subdivisões dos grupos e formações geológicas do município de Paripiranga, BA. Retângulo vermelho – local da Furna do Cazuza



Fonte: O autor (2024).

Figura 3 –Esquema estratigráfico para os domínios do Cráton São Francisco (Grupo Estância) e os domínios presentes da Faixa sergipana (Grupos Miaba, Vaza-Barris e Macururé), porção centro-sul da Faixa Sergipana



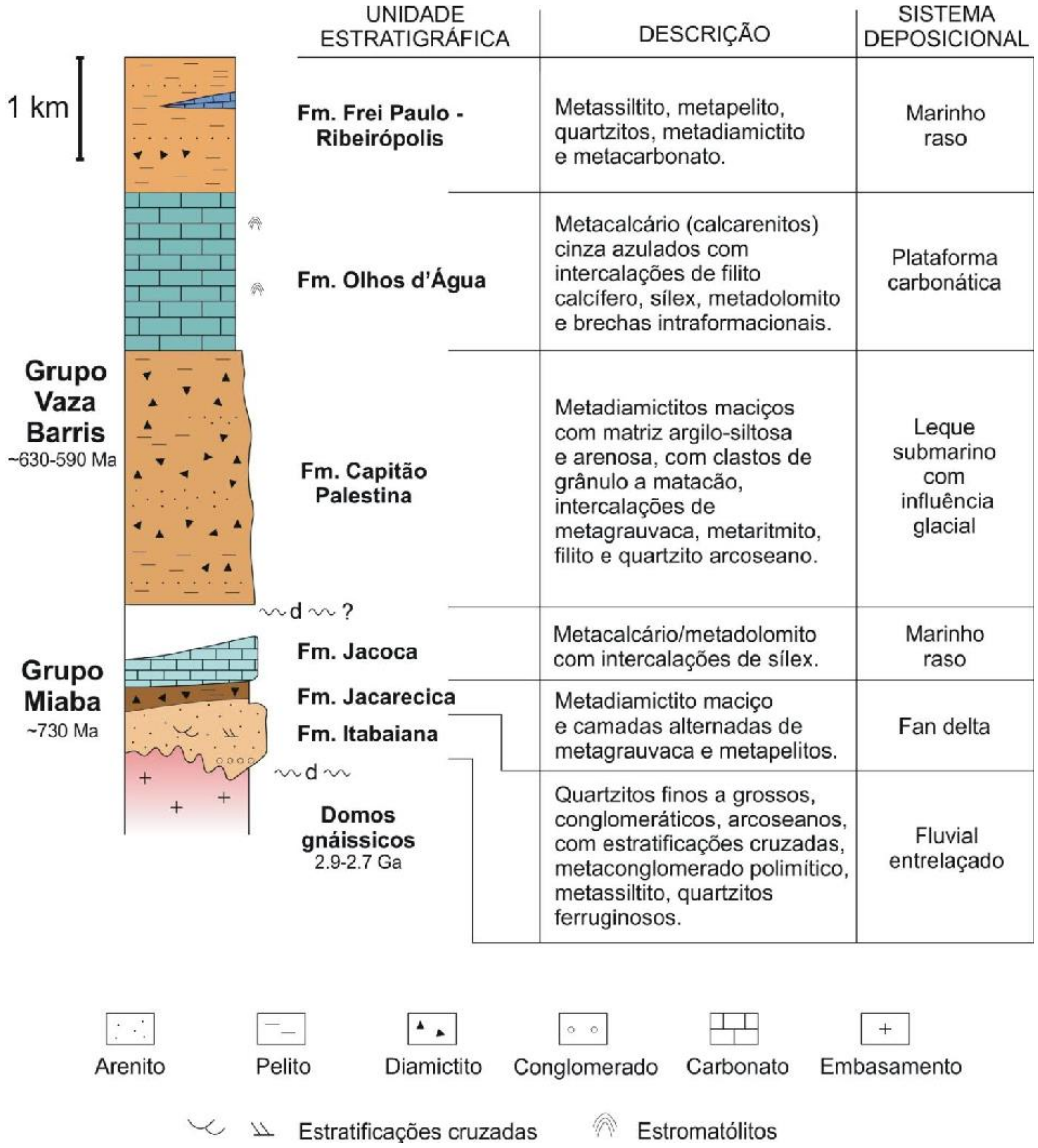
Fonte: Esquema retirado de Uhlein *et al.*, (2011).

A Formação Olhos D'Água é composta por "intercalações de metacalcário médio a fino, calcítico, maciço, de coloração cinza-azulada, e metacalcilutito, com laminação plano-paralela bem evidente" (Uhlein *et al*. 2011ª; 2011b; Figura 4).

A descrição e composição litológica: "metacalcários cinza azulado com intercalações de filito calcífero, metadolomito e brechas intraformacionais" – possibilitou a inferência de um sistema deposicional de Plataforma Carbonática para a Formação Olhos D'Água (Silva Filho *et al*., 1997; Sial *et al*., 2010; Uhlein *et al*., 2011ª; 2011b). São definidas quatro unidades geomorfológicas para a região de Paripiranga: Morros e Colinas, Rampa de Colúvios, Planície do rio Vaza Barris e o Platô de Paripiranga (Pereira *et al*., 2017). A área estudada está inserida na unidade Platô de Paripiranga, possuindo uma altitude máxima de 419 m, desenvolvida sobre metacalcários cinzentos, apresentando maciços e dobras, as vezes abertas de dimensões métricas.

As cavernas localizadas no município estão inseridas nas rochas carbonáticas metassedimentares da Formação Olhos D'água (Pereira *et al*., 2017). O depósito fossilífero estudado situa-se em uma cavidade natural denominada Furna do Cazuza, onde zonas de cisalhamento transpressionais seccionaram as rochas carbonáticas, favorecendo a formação da estrutura. A cavidade está localizada na região central de uma dolina com entrada proveniente de um teto colapsado. Apresenta entrada em forma de abismo de aproximadamente 16 metros de altura e um salão central com grande aporte de sedimento clástico e bioclástico, diversidade em espeleotemas: estalactite, estalagmite, coluna, cortina, travertinos, escorrimento de calcita (Figura 5).

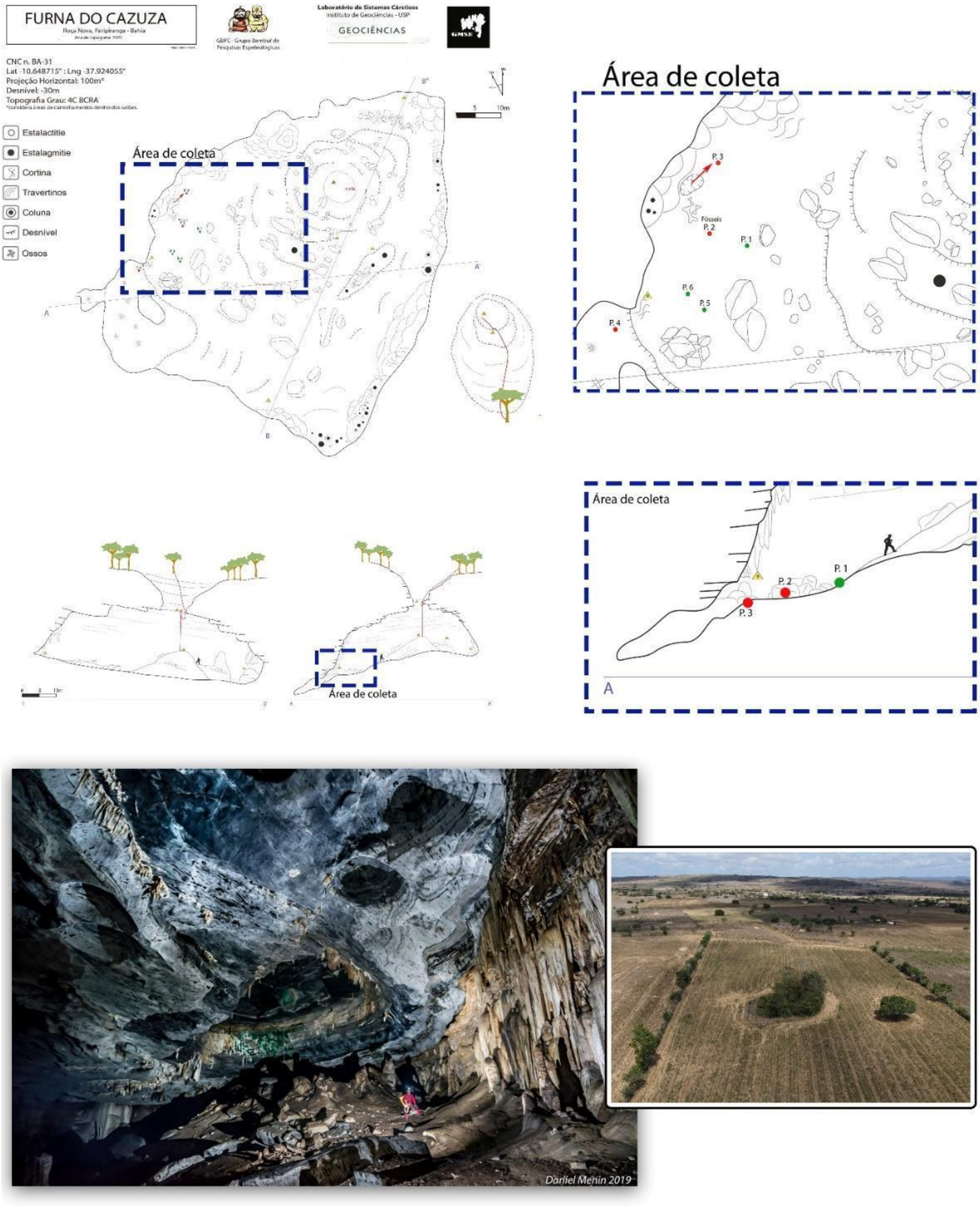
Figura 4 – Descrições de litofáceis e sistemas deposicionais que compõem a coluna estratigráfica dos Grupos Miaba e Vaza Barris



UNIDADE ESTRATIGRÁFICA	DESCRIÇÃO	SISTEMA DEPOSICIONAL
Fm. Frei Paulo - Ribeirópolis	Metassiltito, metapelito, quartzitos, metadiamictito e metacarbonato.	Marinho raso
Fm. Olhos d'Água	Metacalcário (calcarenitos) cinza azulados com intercalações de filito calcífero, sílex, metadolomito e brechas intraformacionais.	Plataforma carbonática
Fm. Capitão Palestina	Metadiamictitos maciços com matriz argilo-siltosa e arenosa, com clastos de grânulo a matacão, intercalações de metagrauvaca, metaritmito, filito e quartzito arcoseano.	Leque submarino com influência glacial
Fm. Jacoca	Metacalcário/metadolomito com intercalações de sílex.	Marinho raso
Fm. Jacarecica	Metadiamictito maciço e camadas alternadas de metagrauvaca e metapelitos.	Fan delta
Fm. Itabaiana	Quartzitos finos a grossos, conglomeráticos, arcoseanos, com estratificações cruzadas, metaconglomerado polimítico, metassiltito, quartzitos ferruginosos.	Fluvial entrelaçado

Fonte: Retirado de Uhlein *et al.*, (2011).

Figura 5 – Area de coleta e topografia da Furna do Cazuza, Paripiranga, Bahia; Fotografias internas e externas da área de estudo. Em menor escala está a imagem aérea da dolina colapsada com pequeno fragmento de vegetação ao centro da imagem. Em escala maior mostra espeleólogos no interior do salão principal da Furna do Cazuza.



Fonte: DJI, Piloto: Johnson Sarmento (2021). Adaptado da topografia e Fotografia de: Daniel Menin (2019).

2.3 VEGETAÇÃO

No município de Paripiranga a vegetação exibe características típicas do domínio morfoclimático da caatinga, com notável amplitude térmica diária tanto durante o período chuvoso, ocorrido entre abril e julho, quanto no seco, entre os meses de outubro e fevereiro. A região, inserida no Polígono das Secas, é classificada como semiárida (CIMAR, 2014). Levantamentos realizados na década anterior identificaram a presença de manchas pontuais de diversas formações vegetais, incluindo Áreas de Transição, Floresta Estacional, Caatinga Arbórea-Arbustiva e Caatinga Arbustiva (CIMAR, 2014; figura 6). Entretanto, observa-se uma grande modificação na paisagem devido à supressão da vegetação nativa, resultando na superioridade de Áreas Antropizadas, predominantemente utilizadas para atividades agrícolas e pecuárias, incluindo cultivo de milho, abóbora, mandioca, feijão, girassol e outras culturas (CIMAR, 2014; Santana *et al.*, 2013).

Figura 6 – Imagem aérea mostrando a variação da vegetação na região do Corredor Vermelho em Paripiranga, Bahia. Nota-se as machas pontuais de vegetação em conflito com as áreas antropizadas

Fonte: O autor (2020).

A Caatinga Arbustiva é composta por vegetação de baixa estatura – até 3m – e ramificados, apresentando estrato contínuo e denso devido a agrupamentos vegetais. Dentre as espécies encontradas nesse ambiente, é comum *Syagrus coronata* (Mart.) Becc. (licurizeiro), *Piptadenia stipulacea* (unha-de-gato), *Myracroduon urundeuva* (Allemão) Engl. (aroeira), *Bumelia sartorum* (quixaba), *Aspilia martii* Baker (mal-me-quer), entre outras. Também é possível encontrar cactáceas como *Cereus jamacaru* DC. (mandacaru) e *Pilosocereus pachycladus* (mandacaru-de-facho ou facheiro) compondo a paisagem (CIMAR, 2014).

Já Caatinga Arbórea-Arbustiva é caracterizada por sua vegetação mais espaçada, com representantes isolados de altura entre 4 e 20 m. As espécies presentes nesse ambiente incluem *Acacia paniculata* (serra-goela), *Dioclea glabra* Benth. (mucunã), *Bougainvillea glabra* Choisy. (buganvília), *Mimosa tenuiflora* (Willd.) Poir. (jurema-preta), *Cedrela* sp. (cedro), entre outras. Ainda, há a presença de espécies de Cactaceae e Bromeliaceae na região (CIMAR, 2014).

Nas Áreas Antropizadas, destinadas ao cultivo agrícola que despertam interesse econômico e à criação de gado bovino e caprino, há uma notável dificuldade no estabelecimento da vegetação nativa. No entanto, existem representantes resilientes frente à degradação humana, como *Andropogon bicornis* L. ("rabo-de-raposa"), *Hyptis cuniloides* Epling. ("alecrim-de-gerais") e *Cnidoscolus urens* (L.) Arthur. ("cansanção"). Além disso, há também a presença de espécies mais próximas ao rio Vaza-Barris, (Mata Ciliar), representadas por *Tabebuia aurea* (Silva Manso) Benth. & Hook. F ex S. Moore. (craibeira), *Aspidosperma pyrifolium* Pichon. (pereiro), *Ziziphus joazeiro* Mart. (joazeiro), entre outras (CIMAR, 2014).

2.4 CLIMA

De acordo com a CIMAR (2014), no relatório de impacto do meio ambiente da região, os dados climáticos foram adquiridos em estações meteorológicas e postos pluviométricos convencionais, em séries históricas de no mínimo 30 anos, bem como informações de boletins diários, semanais e mensais do INEMA, EBDA, EMBRAPA-UNICAMP e INMET: o clima é tropical chuvoso com estação seca.

As temperaturas regionais médias são elevadas, sempre superiores a 18 °C, caracterizando climas megatérmicos. O município de Paripiranga tem, usualmente, uma temperatura entre 22,5ºC e 35ºC. Entretanto, nos levantamentos realizados pela CIMAR (2014), a estação meteorológica que possuía a menor temperatura média mínima fora Paripiranga (19,5 °C), por causa de sua menor continentalidade. O clima da área é caracterizado por apresentar uma precipitação média anual de 880 mm, com estação chuvosa de outono-inverno, notadamente entre os meses de abril a julho, e uma estação seca de primavera-verão (Figura 6).

2.5 RECURSOS HÍDRICOS

2.5.1 Águas Superficiais e Subterrâneas

A rede local de recursos hídricos superficiais apresenta uma distribuição ramificada resultante do seu modelamento, em maior proporção, sobre as rochas metassedimentares. Possui rios temporários como principal característica e apresenta regime fluvial constante (Vieira *et al*, 2005).

Ainda conforme Vieira *et al.* (2005), as características geológicas são favoráveis à acumulação de água em reservatórios superficiais devido ao baixo grau de infiltração das rochas do embasamento. Existem dois domínios hidrogeológicos subterrâneos na região do município: carbonatos/metacarbonatos e metassedimentos/metavulcanitos. Os carbonatos/metacarbonatos ocupam 60% da área municipal e constituem um sistema aquífero desenvolvido em terrenos de rochas calcárias, que têm como característica principal, a presença de cavernas, sumidouros e outras feições erosivas típicas. O domínio hidrogeológico dos metassedimentos/metavulcanitos têm comportamento “fissural”. Devido a não existência de uma porosidade primária, a ocorrência desse tipo de água subterrânea é condicionada a fraturas e fendas: reservatórios aleatórios, descontínuos e de pequena extensão.

3 MATERIAL E MÉTODOS

As atividades de campo foram realizadas no ano de 2019 e 2020, onde primeiro foi realizada uma prospecção nas cavidades subterrâneas da região e posteriormente a escolha da Furna do Cazuza, onde buscou-se entender a composição faunística e sequencialmente as informações obtidas acerca dos espécimes das espécies de mamíferos encontradas.

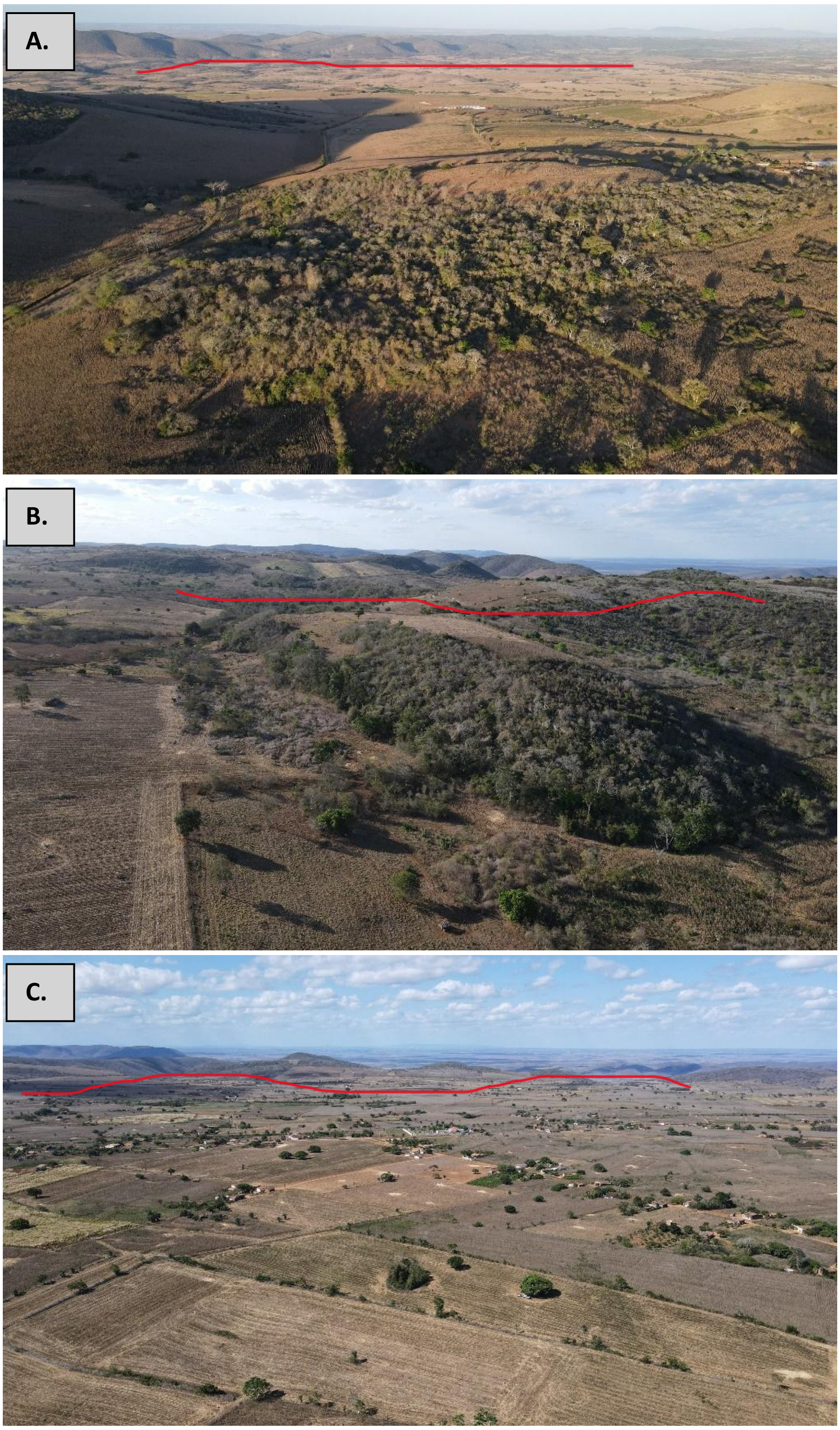
O material estudado encontra-se depositado na coleção científica paleontológica do Laboratórios Integrados de Paleontologia e Espeleologia do Setor de Paleontologia do Museu de História Natural da Universidade Federal de Alagoas (LIPE-SP-MHN-UFAL), Maceió, Estado de Alagoas. Foram seguidas as seguintes etapas: 4.1) prospecção espeleológica e seleção da caverna para estudo; 4.2) método executado em campo; 4.3) método executado em laboratório; 4.4) identificação taxonômica – terminologia; 4.5) Análises de Isótopos estáveis ^{13}C e datação por Radiocarbono ^{14}C.

3.1 PROSPECÇÃO ESPELEOLÓGICA E SELEÇÃO DA CAVIDADE SUBTERRÂNEA

Na etapa de prospecção espeleológica, foi realizado um levantamento das cavidades com registro e/ou relato da presença de fósseis. A equipe do LIPE-SP-MHN-UFAL realizou caminhamento na região e utilizou um drone para um melhor entendimento da área (Figura 7). Essa atividade foi efetuada junto ao grupo que realiza atividades espeleológicas na região (GMSE). Foram utilizadas informações e fotos fornecidas pelo GMSE, relatos de moradores, e dados oficiais das cavidades como geolocalização e algumas características geomorfológicas, disponíveis no Cadastro Nacional de Cavernas do Brasil, Sociedade Brasileira de Espeleologia (CNC-SBE, 2023).

Após o levantamento dos dados obtidos, foram utilizados softwares de geoprocessamento como Qgis e Google Earth, para analisar o posicionamento das cavidades além da plotagem junto a geologia da região (Figura 1 e 2). Por fim, optou-se pela cavidade Furna do Cazuza, onde foi constatada, por meio de fotografias e comunicação social, a presença de grandes ossos fossilizados em seu interior.

Figura 7 – Imagens capturas por drone da região Cárstica de Paripiranga. **A** e **B,** área do corredor vermelho, onde tem a maior concentração de cavernas da região, ao fundo da imagem é possível ver a transição da geomorfologia Platô de Paripiranga para Morros e Colinas. **C**, Localidade de Roça Nova, onde a dolina na qual a Furna do Cazuza está situada. Linha vermelha, transição da geomorfologia



Fotos: O autor (2020).

3.2 MÉTODO EXECUTADO EM CAMPO

Para a realização da entrada e execução dos trabalhos na cavidade, foram analisados os critérios: entrada e saída da caverna; riscos biológicos presentes na entrada (presença de casas de maribondos, vespas e colmeias de abelhas); tempo de execução da campanha; coleta e remoção dos fósseis e sedimentos; e principalmente a segurança e proteção da equipe durante a atividade.

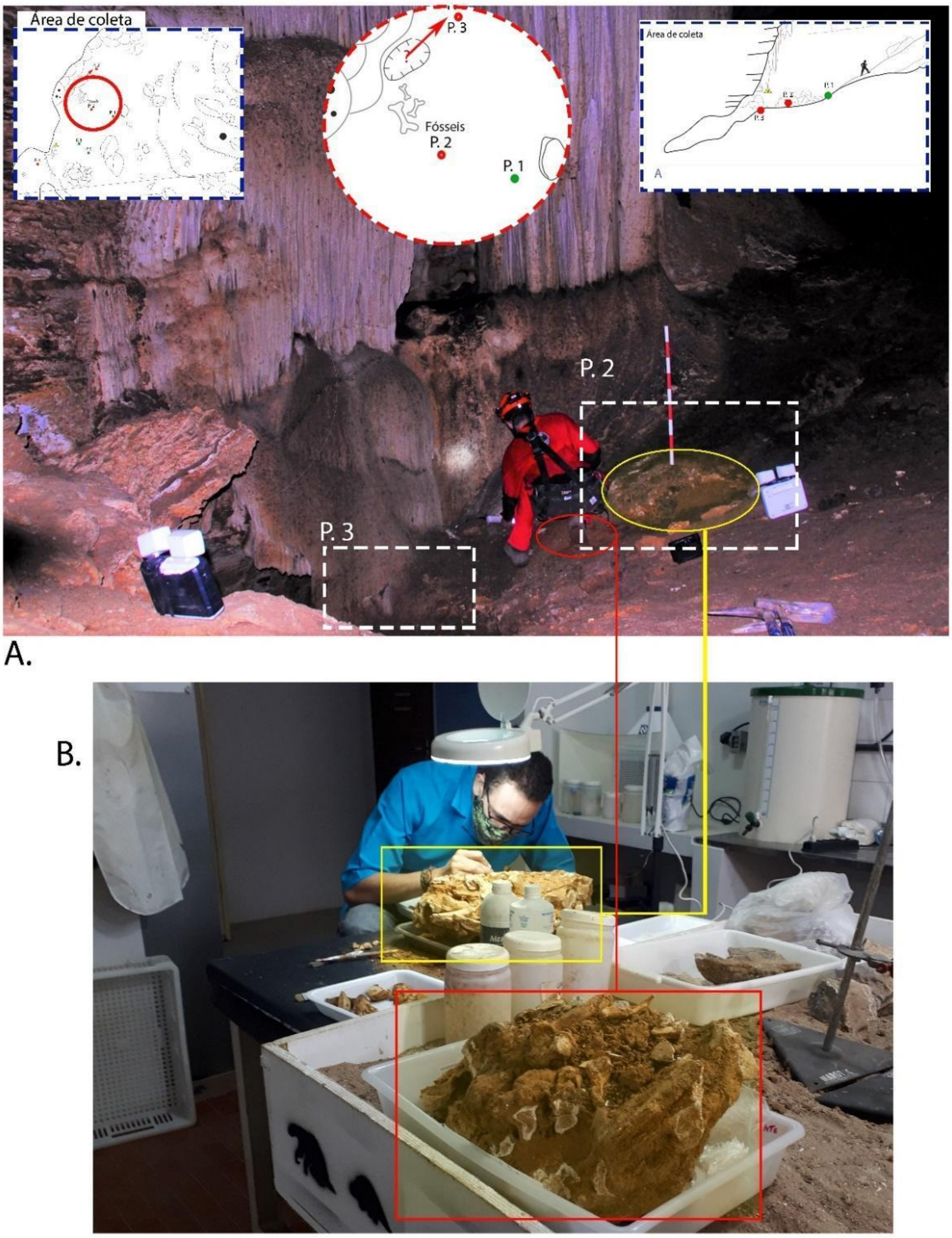
Para a execução da entrada e saída da caverna que tem como única e principal entrada um abismo, foi instalada uma infraestrutura de andaimes e uma escada, buscando não apenas otimizar a eficiência temporal das atividades, mas também, principalmente a segurança da equipe. A infraestrutura constou de 26 andaimes instalados em base de quatro pontos, reforçados com cordas em cada conexão, com pontos de ancoragens distribuídos em cada lado do andaime (Figura 8). Adicionalmente a cada membro da esquipe foram utilizados equipamentos especializados em técnicas verticais (ex. cordas ascensor, descensor, cintos e cadeiras de segurança, mosquetões, polias e trava quedas), com o intuito de amplificar a segurança durante a execução das tarefas.

Figura 8 – Estrutura montada para execução de atividades de pesquisa dentro da caverna Furna do Cazuza. A direita – membro da equipe descendo por uma escada acoplada a um trecho do andaime

Fonte: O autor (2020).

Durante a prospecção na região hipógea da Furna do Cazuza, buscou-se primariamente os fósseis citados pelos moradores, bem como priorização das áreas mais propícias de deposição de sedimentos e restos esqueletais. Foi considerada a topografia da região hipógea, as drenagens em seu interior e prováveis destino de deposição de sedimento e fósseis. Durante a campanha, além dos fósseis localizados e coletados *in situ* pela equipe, foram encontrados alguns espécimes amontoados em alguns pontos da caverna, consideramos aqui que por ação humana, indicando uma possível extração em outro momento. A equipe deu prioridade para a coleta do material que estava em zona de drenagem, e que com o tempo se perderia devido à ação intempérica da água. Cada ponto de coleta no interior da caverna recebeu um nome Ponto_x (onde x é correspondente ao número; Figura 9)

Figura 9 – Principais pontos de extração de fósseis. **A**. P.2 local onde foi concentrada escavação e coleta. **B**. Tratamento dos blocos em laboratório. Vermelho, elementos axiais e cranianos. Amarelo, elementos pós cranianos. Adaptada da topografia realizada pelo Grupo Bambuí, MG (2020) – Localização: Roça Nova



Fonte: A. Maria A. Souza(2020); B. Jorge L. L. Silva(2021).

As coletas dos materiais paleontológicos e sedimentológicos proveniente das cavernas encontradas em Paripiranga, com maior foco para a Furna do Cazuza, foram efetuadas com o auxílio de instrumentos como martelos de geólogos, picaretas, pás, talhadeiras, pincéis e colher de pedreiro. Todos os materiais passaram pelo processo de embalagem, proteção com plástico bolha e receberam etiquetas com identificação para serem transportados ao laboratório para tratamento, estudo e tombamento na coleção de Paleovertebrados do Laboratório Integrados de Paleontologia e Espeleologia do setor de paleontologia do Museu de História Natural da Universidade Federal de Alagoas (LIPE-SP-MHN-UFAL) (Figura 10). Além das peças isoladas coletadas, dois blocos foram retirados, um com ossos cranianos e outro com pós-craniano.

Figura 10 – Registro dos procedimentos práticos de coleta – proteção, embalagem, aplicação de etiqueta para transporte

Fonte: Maria Souza (2020).

3.3 MÉTODO EXECUTADO EM LABORATÓRIO

Todo o material foi retirado de seus invólucros, deixando separados por alguns dias em suas embalagens buscando a redução da umidade aprisionada. Cada material foi posto em bandejas que recebiam uma numeração para controle no tratamento, sendo cada uma identificada com as informações inseridas durante a coleta evitando a mistura de camadas e elementos fragmentados provenientes do transporte.

Após a redução da umidade, ao ar livre e temperatura ambiente, os ossos eram retirados para limpeza e lavagem quando possível, para retirada do sedimento mais grosso para posteriormente serem montados ou colados quando necessário. Os sedimentos de cada saco foram separados para posterior peneiramento e análise sedimentológica, tendo como objetivo encontrar fragmentos dos ossos dos mamíferos de maior porte e para possíveis fósseis de pequenos vertebrados.

Dentre o material isolado coletado foram retirados dois blocos, sendo eles tratados de maneira diferente pois apresentavam um grau de cimentação por calcita. Com intuito de auxiliar e facilitar a remoção dos elementos ósseos, em adição à utilização de cinzeis, micro retífica, ponteiras de diferentes calibres e martelo, foi utilizada a aplicação de ácido clorídrico (HCl) à

30% e 20%, visando a desagregação do material cimentado e incrustado. A aplicação em tal proporção não atacavam a integridade dos ossos. O tempo de extração dos ossos variou de acordo com grau de cimentação.

3.4 IDENTIFICAÇÃO ANATÔMICA E TAXONÔMICA

Os materiais coletados e tombados correspondem a um total de 116 ossos, distribuídos em apendiculares e axiais, os quais passaram por todo o processo de tratamento, identificação e descrição. Para identificação taxonômica e osteológica, seguimos as classificações propostas por Paula Couto (1979) e Cartelle (1992, 1999) literaturas especializadas Scillato-Yané (2005) para Cingulata, Cartelle *et al*., (2009), Perez *et al*. (2010), Miño-Boilini, (2012 e 2016), Corona *et al*. (2013), Cartelle *et al*., (2019), Boscaini *et al*., (2020) e Nieto *et al*. (2021) para *Eremotherium laurillardi* e *Catonyx cuvieri*.

Alguns materiais foram identificados ao serem comparados com materiais de coleções do Setor de Paleontologia do Museu de História Natural da Universidade Federal de Alagoas; da coleção Paleontológica da Universidade Federal de Pernambuco (DGEO-CTG-UFPE); da coleção do Museu de Ciências Naturais da Pontifícia Universidade Católica de Minas Gerais (MCN-PUCMINAS) e do acervo do Museu de História Natural e Jardim Botânico da Universidade Federal de Minas Gerais (UFMG).

3.5 ANÁLISES ISOTÓPICA (δC^{13} e $\delta^{18}O$)

Para determinação da composição isotópica de carbono e oxigênio foram extraídas amostras de esmalte dentário e amostras de tecido ósseo. No processo de tratamento dos ossos, um osso longo de pequeno mamífero foi encontrado junto com sedimentos e sementes dentro do crânio de *C. cuvieri*. As análises foram realizadas no *Center for Applied Isotope Studies of the University of Georgia (Georgia, USA).*

As amostras foram processadas seguindo a metodologia realizada por Cherkinsky (2009). Buscando remover a superfície absorvida e os carbonatos secundários, o osso triturado foi tratado com ácido acético 1N diluído. O dióxido de carbono evoluído foi removido do interior dos fragmentos da amostra por meio da evacuação periódica, permitindo ainda a ação do ácido fresco até mesmo nas micro superfícies. Após a amostra está quimicamente limpa foi reagida sob vácuo com ácido fosfórico a 100% para dissolver o mineral ósseo e liberar o dióxido de carbono (CO_2) da bioapatita.

Utilizando o método de Vogel *et al*. (1984) e Cherkinsky (2009) o dióxido de carbono resultante foi purificado criogenicamente dos outros produtos da reação e convertido cataliticamente em grafite. As proporções de $^{14}C/^{13}C$ do grafite foram medidas usando o espectrômetro de massa do acelerador CAIS de 0,5 MeV. Foi feita uma comparação entre as proporções das amostras e a proporção medida de ácido oxálico I (NBS SRM 4990). As proporções de $^{13}C/^{12}C$ da amostra foram medidas separadamente usando um espectrômetro de massa de proporção de isótopo estável e expressas como $\delta^{13}C$ em relação ao PDB, com um erro de menos de 0,1‰.

Os valores resultantes das análises foram descritos usando a notação delta notation $\delta = [(R_{sample}/R_{standard} - 1) \times 1000]$ (Coplen, 1994). Para evitar a confusão na apresentação das razões isotópica foi seguida a recomendação da *Commission on Atomic Weights and Isotopic Abundances of the International Union of Pure and Applied Chemistry*. Os padrões de referência para os valores de isótopos de carbono ($R = {}^{13}C/{}^{12}C$) e de oxigênio ($R = {}^{18}O/{}^{16}O$) são v-PDB (*Vienna Pee Dee Belemnite*) e v-SMOW (*Vienna Standard Mean Ocean Water*), respectivamente (Coplen, 1995).

3.5.1 Interpretação dos dados de $\delta^{13}C$ e $\delta^{18}O$

Fixando o carbono por meio do Ciclo de Calvin, as plantas de metabolismo fotossintético C_3 abrangem 85% da biomassa das plantas terrestres, representadas pelos, arbustos, árvores e gramíneas de alta latitude, alta elevação e de estações frias de crescimento (McFadden, 2005). Por outro lado, as plantas de metabolismo fotossintético C_4 fixam o carbono usando o ciclo Hatch-Slack e correspondem a 5-10% da biomassa vegetal terrestre (gramíneas e herbáceas; Ehleringer and Cerling, 2002). Já a última e com menor porcentagem de plantas terrestres a terceira via, CAM (*Crassulacean acid metabolism*) que incluem as suculentas (McFadden, 2005).

Sabendo da influência da elevação que as assinaturas das plantas C_3 sofrem a altitudes superiores a 3000 metros (Cabido *et al*., 1997; McFadden, 2005), nós desconsideramos tal influência para o estudo, já que o município de Paripiranga tem elevação de 430 metros, não exibindo assim altos valores.

A interpretação dos valores isotópicos de carbono ($\delta^{13}C$) encontrados a partir de dentes e ossos mamíferos herbívoros de médio a grandes porte, apoiaram-se nos valores fracionados da via fotossintética da planta consumida (C_3 e C_4; Koch, 2007). Plantas C_3 valores menores de $\delta^{13}C = -27 \pm 3$ ‰, plantas C_4 valores maiores de $\delta^{13}C = -13 \pm 2$‰ e por fim, as plantas CAM com valores intermediários entre C_3 e C_4 (McFadden, 2005; Koch, 2007). Aqui consideramos o valor padrão de enriquecimento em herbívoros em +14 ‰ ($\varepsilon^*_{\text{bioapatite-diet}}$; Cerling e Harris, 1999), dessa maneira os animais que se alimentam de plantas C_3 exibem valor -13‰, plantas C_4 valor 1‰, e entre eles uma alimentação de ambas as plantas. Onde Valores $\delta^{13}C < -13$‰ apresentam dieta exclusiva de plantas C_3 (*browser*); valores $\delta^{13}C > 1$‰ tem dieta exclusiva de plantas C_4 (*grazing*); e valores entre $\delta^{13}C$ -11‰ e 3‰ tem dieta mista composta por planta C_3 e C_4.

Nós utilizamos o *Dietary mixing models* de Phillips (2012), para medir a proporção de diferentes plantas na dieta do animal, sendo f_1 = planta C_3 (δ C_1), f_2 = planta C_4 (δ C_2) e $\delta^{13}C_{mix}$ correspondendo as assinaturas de isótopos de carbono obtidas para as espécies analisadas. Aplicando os valores enriquecidos de C_3 = -13‰ e C_4 = 1‰, juntos as equações (2) e (3):

$$\delta^{13}C_{mix} = \delta^{13}C_1 f_1 + \delta^{13}C_2 f_2 \qquad (2)$$

$$1 = f_1 + f_2 \qquad (3)$$

Nós consideramos o proposto por Domingo *et al.* (2012) e replicado por vários autores (e.g. Omena *et al.*, 2021; Dantas *et al.*, 2020; 2021), para interpretar os habitats da fauna estudada, encontrada nas cavernas em Paripiranga, onde valores entre −17‰ e −12‰ representa floresta de baixa densidade; −12‰ e −7‰, savana arbórea; −7‰ e −2‰, arbóreo para savana aberta; e, −2‰ e 6‰, savana aberta.

Os valores de oxigênio em *vSMOW* foram obtidos da conversão dos valores em vPDB, por meio da equação (4) (Coplen *et al.*, 1983):

$$\delta^{18}O_{vSMOW} = 1.03092 \text{ x } \delta^{18}O_{vPDB} + 30.92$$

Já ao tratar de isótopos estáveis de oxigênio em mamíferos, Koch (2007) relata que a composição de oxigênio é refletida pelos ciclos naturais de entrada (respiração e ingestão) e saída (respiração, transpiração e excreção) do organismo. Bocherens e Drucker (2013) apontaram que o oxigênio é absorvido principalmente por meio da ingestão da água e do consumo de alimentos. Os valores de isótopos de oxigênio nos tecidos vegetais são, em maioria dos casos, semelhantes aos da precipitação local de corpos d'água (e.g. lagoas, rios e lagos), permitindo comparar com os $\delta^{18}O$ nesses mamíferos (MacFadden et al., 1999; Sponheimer e Lee-Thorp, 2001).

A concentração de δ^{18}O presente nos tecidos de mamíferos fósseis ainda permite inferir sobre a variações de temperatura e aridez. A temperatura é o principal fator impulsionante nas variações dos valores de δ^{18}O em regiões temperadas, enquanto a quantidade de precipitação é o que impulsiona essa variação em regiões tropicais com temperaturas acima de 20°C, exibindo valores mais baixos com o aumento da quantidade de precipitação (Dansgaard, 1964) permitindo uma variação sazonal bem marcada dos registros de isótopos de oxigênio nos tecidos de fósseis de mamíferos (Silva et al., 2023). Portanto, em regiões tropicais, níveis mais elevados de δ^{18}O sugerem períodos mais secos, ao passo que níveis mais baixos indicam um aumento da umidade devido à alta precipitação.

4 RESULTADOS

Os resultados apresentados nesta tese estão estruturados na forma de artigos científicos em periódicos na área de Geociências da Coordenação de Aperfeiçoamento Pessoal (CAPES), seguindo o regimento do Programa de Pós-Graduação de Geociências da Universidade Federal de Pernambuco (PPGEOC/UFPE).

O Artigo 1 é intitulado "***Representatives of the Order Pilosa and Cingulata, Furna do Cazuza (Pleistocene-Holocene), Paripiranga, Bahia, Northeastern Brazil***" submetido e sob análise, no periódico Journal of South America Earth Sciences de Qualis Capes A2. Neste manuscrito é feita uma descrição taxonômica/anatômica de restos esqueletais de representantes da megafauna vivente durante o período que compreende a transição Pleistoceno-Holoceno, fazendo correlação com representantes das famílias Pilosa e Cingulata, e breves considerações sobre o ambiente.

O Artigo 2 é intitulado "***Isotopic paleoecology (δ^{13}C), chronology, and paleoenvironmental reconstruction (δ^{13}C, δ^{18}O) of Late Quaternary cave deposits from the Paripiranga, Bahia, Brazil***" submetido na revista Quaternary Science Reviews de Qualis Capes A1. Abordará os resultados obtidos por meio de análises geoquímicas, isótopos de C e O, datações por AMS de diferentes fósseis de mamíferos encontradas em cavernas da região. Ele apresenta dados inéditos sobre a cronologia, dieta, paleoecologia e paleoambiente da região.

O Artigo 3 é intitulado "***The Paleontological and Speleological Wealth of the Municipality of Paripiranga, Bahia, Brazil: Potential for Heritage Education and the Establishment of Memory Spaces***" submetido na revista Terrae Didatica de Qualis Capes B1. Esse manuscrito aborda a importância do patrimônio espeleológico e paleontológico na região de Paripiranga, Bahia, como valiosa fonte de riqueza cultural e natural, apontando diferentes criações de espaços de preservação e divulgação científica como essenciais para conexão da comunidade com o seu passado e presente.

4.1 ARTIGO 1 – REPRESENTATIVES OF THE ORDER PILOSA AND CINGULATA, FURNA DO CAZUZA (PLEISTOCENE-HOLOCENE), PARIPIRANGA, BAHIA, NORTHEASTERN BRAZIL

Seguindo as normas da revista

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ABSTRACT

Located in the Northeast of Brazil, the city of Paripiranga, State of Bahia, is situated in a karst region called Supergrupo Canudos. The locality boasts a high number of natural cavities, some of which contain Pleistocene mammal fossils and remains of contemporary vertebrates. The cave locally known as Furna do Cazuza is a deep natural cavity in Proterozoic limestone, with a vertical entrance of sixteen meters in depth, resembling an abyss, serving as natural traps for many animals, especially mammals. The cave has a large area at its entrance, with a significant influx of sediment and a considerable quantity of bones, some of which have already been collected. The collected bone material (appendicular and part of a skull) belongs to three individuals: an armadillo and two giant ground sloths. The osteoderms were attributed to the Pampatheriidae *Holmesina* sp., and the most abundant bone material to the Megatheriidae *Eremotherium laurillardi* and the Scelidotheriidae *Catonyx cuvieri*. This study presents the largest number of bones of *C. cuvieri* attributed to a single individual in a cave. As paleontological research advances, the understanding of the diversity of the past fauna during the Pleistocene in the municipality of Paripiranga and the surrounding region continues to expand. The caves are still under study, and their fossiliferous richness has not been fully measured and identified.

Keywords: Megafauna, Cingulata, Pilosa, Ground sloth, Furna do Cazuza

1. INTRODUCTION

The Brazilian territory is rich in natural limestone cavities, and according to the latest survey provided by the Centro Nacional de Pesquisa e Conservação de Cavernas/Instituto Chico Mendes de Conservação da Biodiversidade (CECAV/ICMBio), in 2022, there are 23.378 registered caves in Brazil. The state of Minas Gerais leads with 10.570 caves (46.72%), followed by Pará in second place with 2.858 (12.63%), and Bahia in third with 1.694 (7.49%). The report also cross-references data on rock classes and cave occurrences in Brazil. In this way, it is observed that the category of carbonate rocks holds the highest number of caves, corresponding to 12.267 (52%) of the database. According to Cadastro Nacional de Cavernas do Brasil, Sociedade Brasileira de Espeleologia (CNC-SBE; 2023), the municipality of Paripiranga ranks twenty-first nationally and fourteenth in Bahia in terms of the number of natural cavities.

Natural cavities are among the most relevant fossil deposits in country, featuring extensive accumulations of Quaternary mammal fossils, particularly in the Brazilian Intertropical Region (BIR) (Cartelle, 1999; expanded by Oliveira et al., 2017). This region is characterized by diverse vegetation types, ranging from closed to more open environments (Lessa et al., 2021). The documentation of paleovertebrates in different regions of Bahia is well-established, indicating a broad diversity of mammal taxa, including Pilosa, Carnivora, Cingulata, Proboscidea, Notoungulata, Perissodactyla, Certartiodactyla, Litopterna, Rodentia, Didelphimorphia e Chiroptera (Cartelle, 1992; 1999; Scherer et al., 2017; Silva et al., 2019; Eltink et al., 2020; Greco et al., 2022).

The mammals that lived during the Pleistocene in the region that is now northeastern Brazil are well documented in the literature (Cartelle, 1992; 1999; Ximenes, 2009; Araújo-Júnior et al., 2017; Rocha-dos-Santos, 2017; Nascimento et al., 2020; Faria et al., 2021). This area is part of the BIR (Oliveira et al., 2017; Figure 1), where several types of sedimentary deposits with the presence of Quaternary fossils are recognized (Oliveira et al., 2013; Asakura et al., 2016; Oliveira et al., 2017; Nascimento et al., 2020). Considering the diversity of the types of sedimentary deposits present in the BIR (ponds, lagoons, rock shelters, riverbeds, and natural cavities), we focus here on the natural cavities of Brazil.

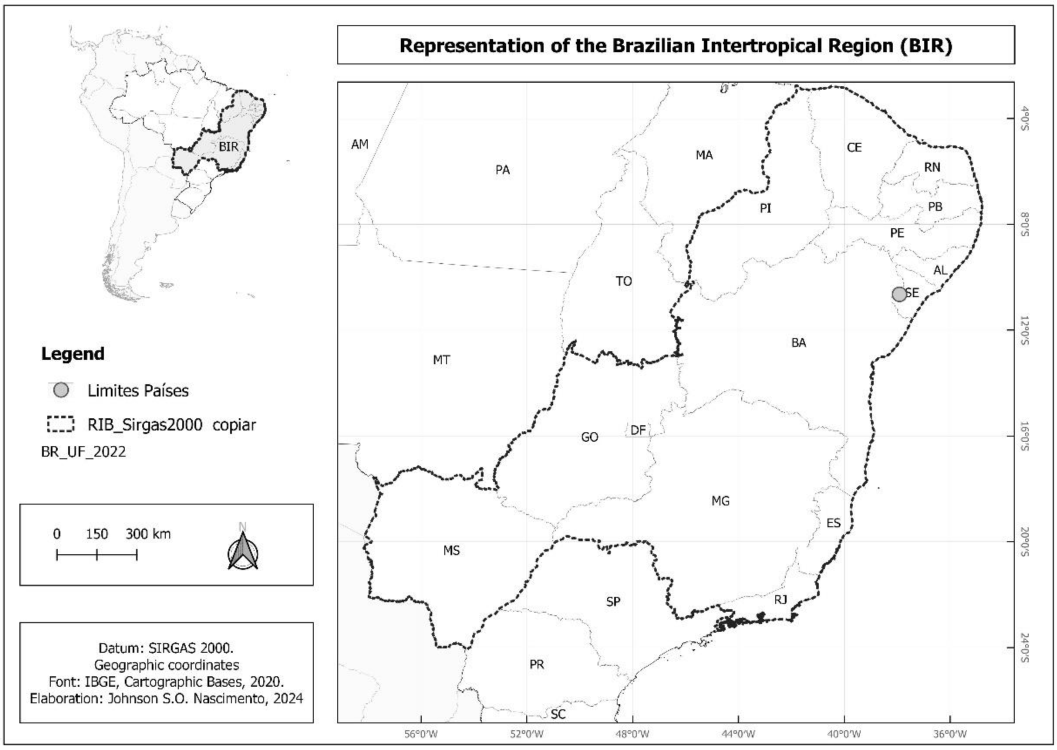


Figure 1. Map showing the Brazilian Intertropical Region (BIR; represented by the dotted line; sensu Cartelle 1999 expanded by Oliveira et al., 2017).

In the last few years, research activities in the region of the municipality of Paripiranga, in northeastern Bahia, have intensified. Initially, the studies were just preliminary research into the paleofauna that inhabited the region (Dantas, 2005; Donato et al., 2008; Dantas et al., 2010; Silva et al., 2012). Researchers at the Paleontology laboratories of the Universidade Federal de Pernambuco (PALEOLAB-UFPE) and the Setor de Paleontologia of the Museu de História Natural of the Universidade Federal de Alagoas (SP-MHN-UFAL) have expanded their studies and obtained more results from the region on the taphonomic and sedimentological processes that occurred to the fossilized skeletal remains (Lima, 2017; Nascimento, 2018).

However, the data obtained on the fauna by Lima (2017) in studies conducted in one of the cavities in the region, and after dating, resulted in an age of 560 years BP (+/-20), indicating that they are recent with little diversity of fossil mammals, with bones of *Pecari tajacu* = *Dycotiles tajacu* being the most abundant. On the other hand, Nascimento (2018) employs various methods in the study of the paleofauna found in the Borboletas Cave, conducting a study covering taxonomy, morphological description, sedimentology, and brief taphonomic considerations.

Among the various caves found in the region, Nascimento et al., (2020), point out the Borboletas Cave as the richest in megafauna taxon diversity. Other studies in the locality only mention occurrence citations (e.g., Dantas, 2005; references cited). Based on the limited available data on the Pleistocene megafauna of the municipality of Paripiranga, this contribution aims to identify and describe the specimens of Pilosa and Cingulata found in another cave in the region, called Furna do Cazuza, providing new data for a better representation of the region's past environment. Additionally, it conducts a brief discussion within the paleozoogeographic and paleoenvironmental context of Brazil.

2. STUDY AREA: LOCATION, GEOLOGY AND GEOMORPHOLOGY

The study area is in the municipality of Paripiranga (Altitude 430 m; 10°41'00"S, 37°51'00"O), in the northeast of the state of Bahia, bordering the municipalities of Bahia, Adustina to the west and Coronel João de Sá to the north and bordering the state of Sergipe to the east and south (Vieira et al., 2005; Figure 2).

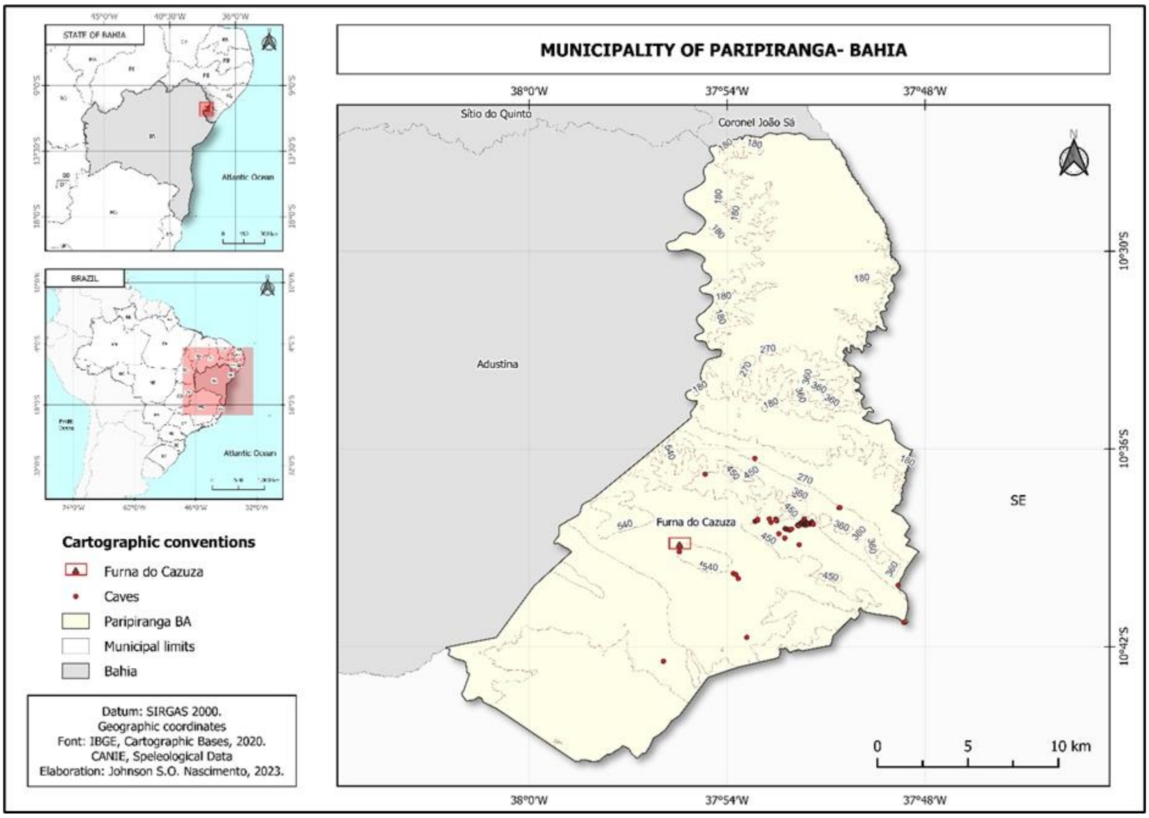


Figure 2. Location map of Furna do Cazuza, municipality of Paripiranga, Bahia, Brazil.

In the geological context, the municipality is situated within the Vaza Barris domain. The domain is characterized by Uhlein et al. (2011) in a hierarchical order from the base to the top as follows: Miaba Group (Itabaiana Formation < Jacarecica and Jacoca Formations) and Vaza Barris Group (Capitão Palestina Formation < Olhos D'Água Formation < Frei Paulo-Ribeirópolis Formation).

The description and lithological composition (bluish gray metacarbonates with intercalations of calcareous phyllite, metadolomite, and intraformational breccias) allowed the inference of a Carbonate Platform depositional system for the Olhos D'Água Formation, where the study area is located (Silva Filho et al., 1997; Sial et al., 2010; Uhlein et al., 2011). Four geomorphological units are defined for the Paripiranga region: *Platô de Paripiranga*, *Morros e Colinas*, *Rampa de Colúvios*, and *Planície do Rio Vaza Barris* (see Pereira et al., 2017).

The fossiliferous deposit studied is a natural cavity called Furna do Cazuza, where transpressional shear zones section the carbonate rocks. The cavity is located in the central region of a doline with an entrance coming from a collapsed roof. It has a chasm-shaped entrance and a central hall with a large amount of clastic and bioclastic sediment, and a diversity of speleothems: stalactite, stalagmite, column, curtain, travertine, calcite ooze (Figure 3).

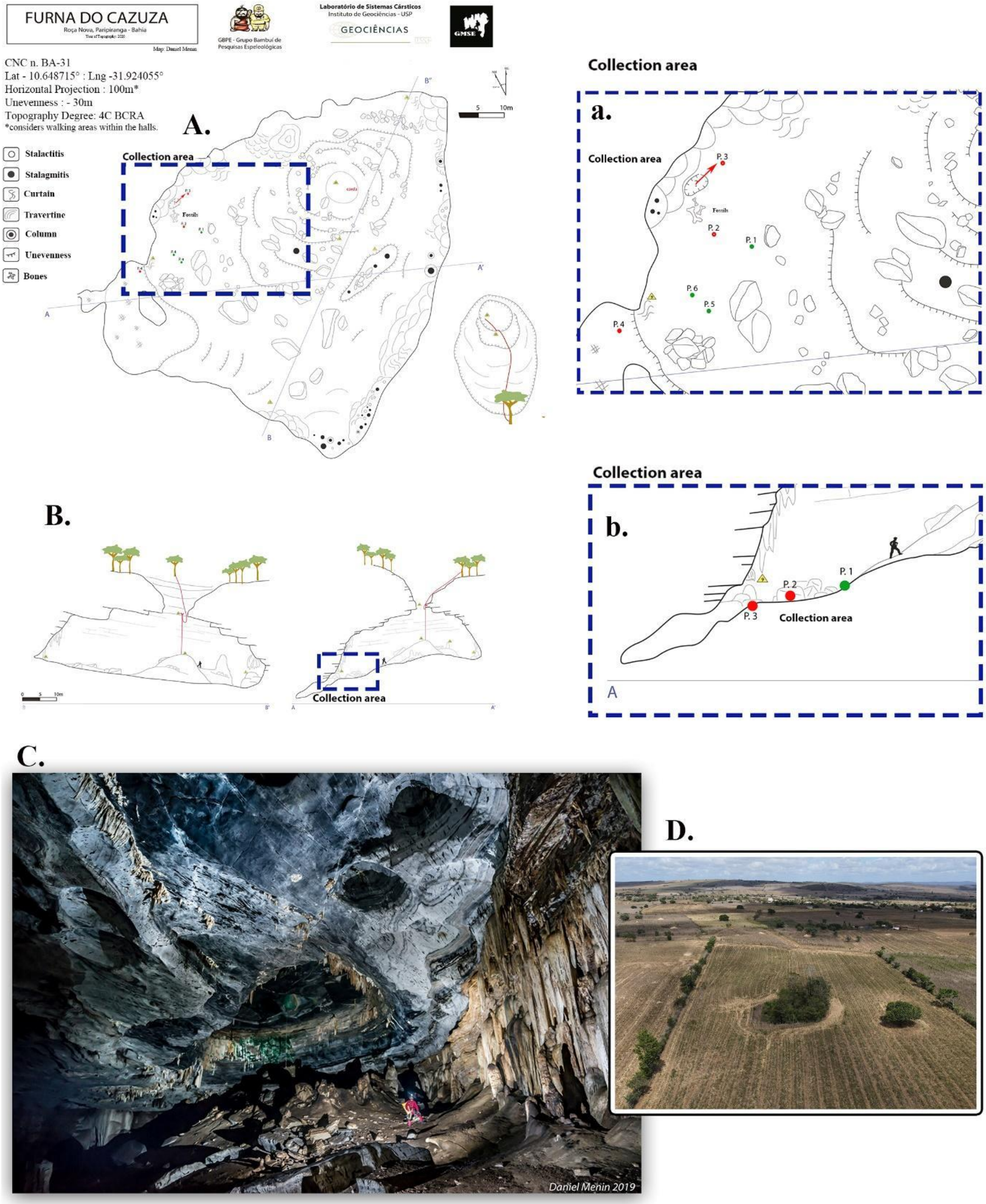


Figure 3. Topography and Collection Area in the Furna do Cazuza Cave, Paripiranga, Bahia, Brazil; **A**. Ground plan; **B**. Longitudinal profile, focusing on the entrance area of the cave; **a**. and **b**. focus of collection areas; **C**. internal photograph of the hall and other speleothems; **D**. external photograph of the sinkhole where the Furna do Cazuza cave is located at the center of the image. DJI, Pilot: Johnson Sarmento, 2021; Photography: Daniel Menin, 2019.

3. MATERIAL AND METHODS

After a literature review and interviews with residents in the Paripiranga region of Bahia, the presence of fossils in the natural cavity known as Furna do Cazuza was confirmed. The material was collected after prospecting activities carried out by the Laboratório de Paleontologia, of the Departamento de Geologia, Centro de Tecnologia e Geociências at the Universidade Federal de Pernambuco (PALEOLAB-DGEO-CTG-UFPE) and the Laboratórios Integrados de Paleontologia e Espeleologia of the Setor de Paleontologia at the Museu de História Natural, Universidade Federal de Alagoas (LIPE-SP-MHN-UFAL) in the year 2020. The researchers received operational support from members of the Grupo Mundo Subterrâneo de Espeleologia (GSME).

To facilitate entry and conduct activities within the underground cavity, a scaffold infrastructure was installed, aiming not only to optimize the temporal efficiency of the tasks but also to ensure the safety of the team during the activities. In addition to the erected structure, specialized devices in vertical techniques (e.g., ropes, ascenders, descenders, safety belts, carabiners) were employed to enhance safety factors during task execution. The collection areas within the cavity are situated in a transition zone between the twilight and aphotic zones. To carry out activities in the aphotic zone, portable reflectors and headlamps were chosen, providing adequate and focused illumination (Figure 4).

The collected material was wrapped in bubble wrap, protected, labeled, and placed in an agricultural plastic box (adapted for collection) to be processed and analyzed at the LIPE-SP-MHN-UFAL. In addition to the isolated pieces collected, two blocks were removed, one with cranial bones and another with postcranial elements. The decision to extract the blocks was made to preserve the bones as well as their taphonomic information (Figure 4). For the dismantling of the blocks and excavation of the bones, a micro rotary tool, chisels, tips of various calibers, and a hammer were used. To assist and facilitate the removal of the bone elements, hydrochloric acid (HCl) at 30% and 20% concentrations was applied, aiming at the disaggregation of the cemented and encrusted material. The extraction time varied according to the degree of cementation.

For the taxonomic and osteological identification of *Eremotherium laurillardi* and *Catonyx cuvieri*, classifications proposed by Cartelle et al. (2009), Perez et al. (2010), Miño-Boilini (2012 and 2016), Corona et al. (2013), Cartelle et al. (2019), Boscaini et al. (2020), and Nieto et al. (2021) were followed. For Holmesina, references from Scillato-Yané (2005), Góis et al. (2012), and Moura et al. (2019) were used. We follow Cartelle (1999) and other references cited here by identifying the late Pleistocene mammals from northeastern Brazil as intertropical, *Holmesina*, *Eremotherium laurillardi*, and *Catonyx cuvieri*. Along with the article, a supplementary list and some measurements of the specimens analyzed and studied here are provided.

Some specimens were identified by comparing them with material safeguarded in the collections of the SP-MHN-UFAL, in the collection of the Museu de Ciências Naturais, Pontifícia Universidade Católica de Minas Gerais (MCN-PUCMINAS), and in the holdings of the Museu de História Natural e Jardim Botânico, Universidade Federal de Minas Gerais (UFMG).

Abbreviations: UFAL, Universidade Federal de Alagoas; LIPE-SP-MHN-UFAL, Laboratórios Integrados de Paleontologia e Espeleologia do Setor de Paleontologia de Museu de História Natural da Universidade Federal de Alagoas; UFPE, Universidade Federal de Pernambuco; PALEOLAB-UFPE, Laboratório de Paleontologia da Universidade Federal de Pernambuco; MCN-PUCMINAS, Museu de Ciências Naturais da Pontifícia Universidade Católica de Minas Gerais; GSME, Grupo Mundo Subterrâneo de Espeleologia. BIR, Brazilian Intertropical Region. mx- lower molar, "x" corresponds to the number of the corresponding tooth; MC – metacarpal.

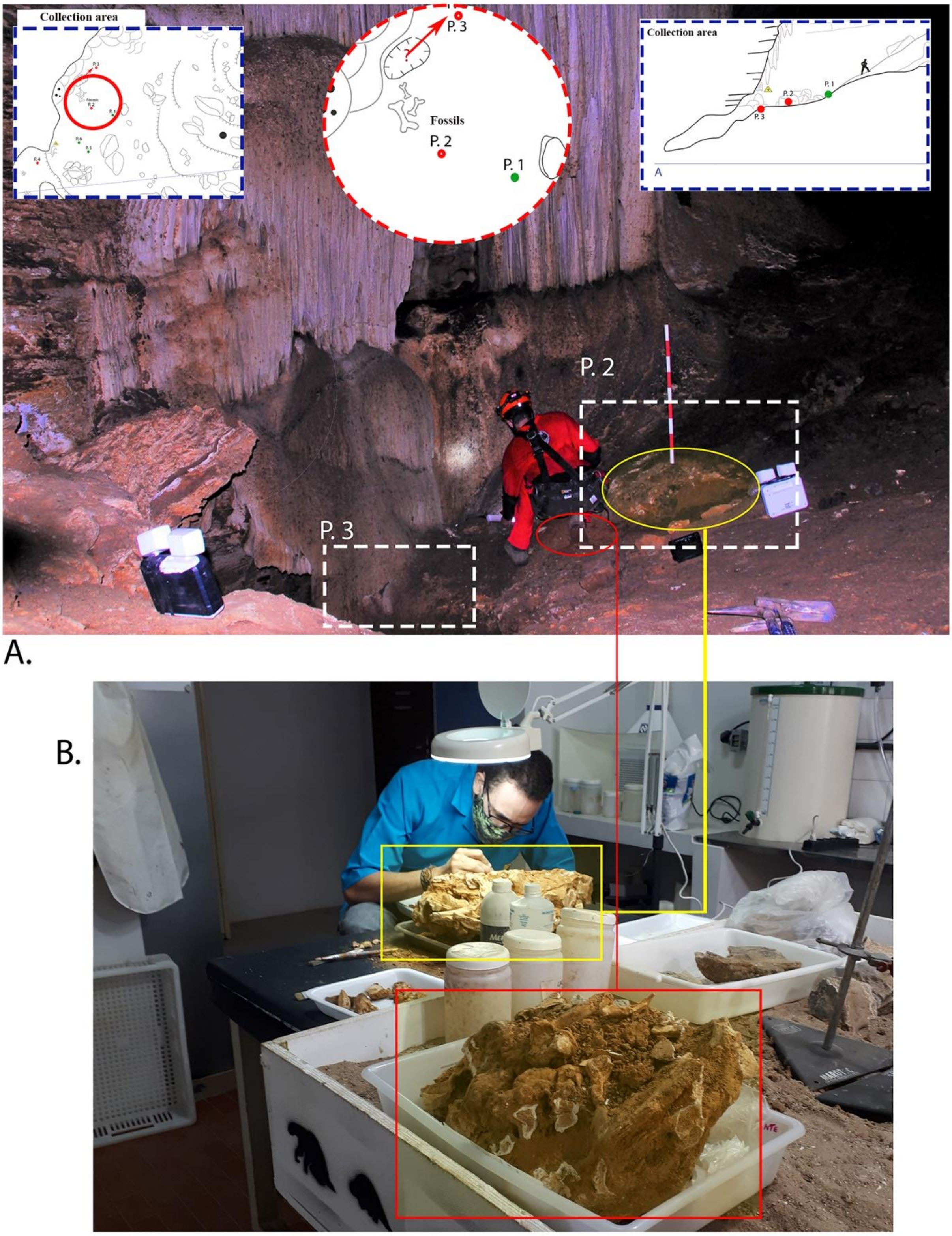


Figure 4. Main fossil extraction points. A. P.2 site where excavation and collection were concentrated. B. Treatment of the blocks in the laboratory. Red, axial, and cranial elements. Yellow, post-cranial elements. Adapted from the topography carried out by the Bambuí Group, MG (2020) - Location: Roça Nova. Photo: Maria Aparecida Souza, 2020.

4. RESULTS AND DISCUSSION

Representatives of the superorder Xenarthra were identified, a clade subdivided into two orders: Pilosa and Cingulata, and some representatives of small mammals found associated with megafauna fossils found in Furna do Cazuza. The completeness found totaled 116 bones, distributed into appendicular and axial. Of the 105 specimens identified, two are from *Holmesina* sp., eleven are attributed to *Eremotherium laurillardi*, and a large part to *Catonyx cuvieri*, totaling 74 specimens.

4.1 Systematic Paleontology

Order CINGULATA Illiger, 1811
Family PAMPATHERIIDAE Paula Couto, 1954
Subfamily PAMPATHERIINAE Paula Couto. 1958
Genus *Holmesina* Simpson, 1930

Material: SP-MHN-UFAL, fixed osteoderms (2190-V; 2191-V)

Description: Osteoderm 2190-V is hexagonal, measures 33.2 mm in diameter, and is 9.2 mm thick (Table 1). It has a shallow concavity on its inner face and a sculpted surface with numerous dots (Figure 5). Specimen 2191-V is largely fragmented and shows a small relief on the surface, pointing to a marginal elevation on its dorsal surface, characteristic of some osteoderms of the genus (Scillato-Yané et al., 2005). Both specimens show limestone encrustation inside (Figure 5).

Chronological and Geographical Distribution: pampaterids are recorded from the middle Miocene to the early Holocene (Góis *et al*., 2015). The genera *Holmesina* and *Pampatherium* have a typical occurrence in South America with a chronostratigraphic distribution between the Pliocene and Pleistocene-Holocene (Kerber and Oliveira, 2008; Góis et al., 2012). The genus *Holmesina* originated in North America and later entered South America during the Great American Biotic Interchange (GIBA), during the Pleistocene (Scillato-Yané *et al*., 2005). In Brazil, *Holmesina* occurs in Rondônia, Bahia, Rio Grande do Sul, Rio Grande do Norte, Paraíba, and Mato Grosso do Sul (Moura, 2019; Moura et al., 2019).

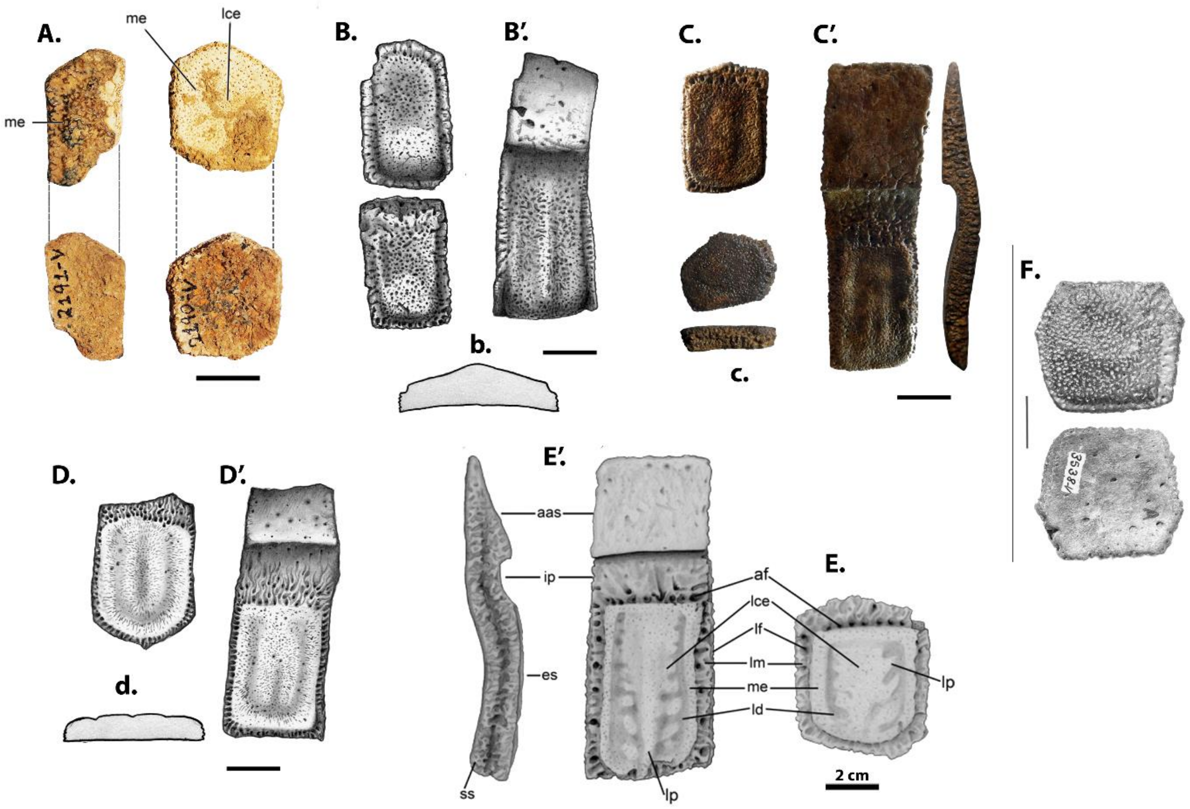


Figure 5. *Holmesina* sp., 2190-V (right) and 2191-V (left), osteoderms, **A**; *H. paulacoutoi*, osteoderms, **B**; *H. cryptate*, osteoderms, **C** (LPP-PV-001 holotype); *P. humbolditi*, osteoderms, **D**; *Tonnicinctus mirus*, osteoderms, **E;** *H. paulacoutoi*, osteodermo, **F.** A-F, fixed osteoderm; B'-E', movable osteoderm. A. dorsal view - above and internal view - below; B-D and B'-E' dorsal view; b-d, lateral view. B and D, Osteoderms depicted in Scillato-Yané et al. (2005); C, species studied by Moura de Jesus et al., (2019); E, osteoderms analyzed by Góis et al., (2015); F, osteoderm MNRJ 3538-V, studied by Oliveira and Pereira (2009). Scale 2 cm. Abbreviations: **aas**, anterior articular surface; **af**, anterior foramina; **es**, exposed surface; **id**, intermediate portion; **lce**, longitudinal central elevation; **ld**, longitudinal depressions; **lf**, lateral foramina; **lm**, lateral margins; **me**, marginal elevation; **lp**, lateral projection; **ss**, sutural surface.

Table 1. Measurements (mm) of pelvic fixed osteoderms of pampatheres. (*) in this article; (1) Moura et al. (2019); (2) Avilla et al., (2022).

	Length	Width
SP-MHN-UFAL 2190-V *Holmesina* sp.*	36,6	33,2
Holmesina cryptae (1)	50,2	34,4
Holmesina paulacoutoi (1)	63	51,5
Holmesina juvenile (2)	36,25	25,76
Pampatherium typum (1)	33,4	30,3
Scirrotherium carinatum (1)	36,16	27,71
Tonnicinctus mirus (1)	48,5	34,2
Vassallia minuta (1)	34,8	31,9

Brief Comparative Remarks: According to Paula-Couto (1979), the most common characteristic among contemporary cingulates is the presence of a carapace subdivided into two shields, a scapular and pelvic. In the Pleistocene of Brazil, the Pampatheriidae are represented by the genera: *Pampatherium* Ameghino 1881, with the species *P. typum* Gervais and Ameghino, 1880 and *P. humboldti* Lund, 1839; here we consider the study by Ferreira et al. (2018), who reviewed the specimens of *Holmesina major* (Lund, 1842), and concluded that they belonged to *P. humboldti*; in addition, the genus *Holmesina* Simpson 1930, with the species; *H. paulacoutoi* (Cartelle; Bohórquez, 1984); *H. rondoniensis* Góis, Scillato-Yané, Carlini e Ubilla, 2012 and *H. cryptae* Moura; Góis; Galliari; Fernandes, 2019; and *Tonnicinctus mirus* Góis, Ruiz, Scillato-Yané, Soibelzon, 2015 (Scillato-Yané et al., 2005; Oliveira et al., 2009; Góis et al., 2012; Moura et al., 2019).

Holmesina is distinguished from *Pampatherium* and *Tonnicintus* by its cranial, dental, and exoskeletal characteristics (osteoderms). In *Pampatherium*, the osteoderms have a more uniform surface with a flatter central area and no central figure, and the more posterior molariforms have trilobulation (Scillato-Yané et al., 2005; Góis et al., 2015). The osteoderms of *T. mirus* have a more denticulated sutural surface than *P. typum* and less than *H. paulacoutoi* and exhibit a central longitudinal elevation that is much lower than the marginal elevation, wide, asymmetrical, and with small, irregular lateral projections, unlike any Pampatheriidae (Góis et al., 2015).

The osteoderms of *Holmesina* are thicker than (Table 1) those of *Pampatherium*, have a much rougher surface and the marginal zone is wide and low around the central area, which is high, being a synapomorphy characteristic (Scillato-Yané, 1982), which can be seen in osteoderm 2190-V (see Figure 5).

Compared to the recently discovered species, *H. cryptae* exhibits structures such as narrower lateral margins on the fixed osteoderms than in *H. paulacoutoi*. They have a lower and less delimited marginal elevation than in any other *Holmesina*, longitudinal depressions, and a well delimited longitudinal central elevation, which is less sculpted and elevated than in *H. paulacoutoi*, but more defined than in *P. humboldti* and *P. typum* (Moura et al., 2019). Scillato-Yané et al. (2005) also show the subtle differences observed in lateral and dorsal views between the osteoderms of some species (Figure 5). Due to the absence of more complete specimens, osteoderms, and cranial elements, identification at the species level was not possible. The materials bear a certain resemblance to those featured in Oliveira and Pereira (2009) (see Figure 5 - specimen MNRJ 3538-V). Some structures compared between the specimens in Figure 5 show similarities, such as the lateral margins and the marginal elevation, noted in the specimens of the genus *Holmesina*, something characteristic observed in this genus and different from *Pampatherium* and *Tonnicintus*.

Order PILOSA Flower, 1883
Family MEGATHERIIDAE Owen, 1842
Subfamily MEGATHERIINAE Gill, 1872
Genus *Eremotherium* Spillmann, 1948
Eremotherium laurillardi Lund, 1842

Material: SP-MHN-UFAL, body of cervical vertebra (1923-V); rib fragment (1927-V); fragment of the humerus (1908-V); right scaphoid (1909-V); left lunar (1910-V); fragments of pelvis (1904-V), left (1906-V) and right (1907-V) calcaneus; metatarsus II (1915-V), fused metatarsus III and IV right (1912-V); right navicular (1911-V); right ectocuneiform (1913-V)

Description:

Vertebra: Although no complete vertebrae were found, specimen 1923-V represents a vertebral body from the cervical region.

Humerus: specimen 1908-V is fragmented, and its distal portion is missing. The preserved region refers to the anterior surface of the proximal region of the humerus, exhibiting a convex shape, corresponding to the area that articulates with the scapula (Figure 6).

Carpals

Scaphoid: The scaphoid has a characteristic convex dorsal surface and a concave palmar surface. The right specimen 1909-V is fragmented; in distolateral view, only one of the accessory facets can be seen, which connects to the magnum and lunar. The anatomical features are similar to those described in De Iuliis and Cartelle (1994).

Lunar: Specimen 1910-V corresponds to a left lunar, a massive and irregular bone (Figure 6). The lateral surface shows an articular facet for the cuneiform, which is narrow anteroposteriorly and elongated dorsopalmarly, with a slight concavity. The lunar also articulates to the unciform on its concave laterodistal facet; to the magnum on its most distal region, displaying a dorsopalmarly convexity; and to the scaphoid through its medial face with a concave shape. The surface of a larger diameter is located in the proximal region, corresponding to a dorsopalmarly

Pelvis: Specimens 1904-V consist of fragments of the pelvic girdle. The proportions of the recovered fragments align with the species description. The dorsal edge tends to be less projected in relation to the sacral vertebrae. In this species, the ileum is laterally expanded and projects cranially to a lesser extent. Fragments from both sides of the pelvis were identified among the fallen material.

Calcaneus: In specimen 1906-V, the left calcaneus, the most posterior portion of the *tuber calcis* is absent (Figure 6). In its proximal region, it is possible to see only one facet of the two connecting faces with the astragalus, and the *sulcus talis* is still visible. In plantar view, there is a large area that has been worn down by water. 1907-V corresponds to the right calcaneus; it is more damaged than the left (1906-V), and only the proximal portion and one of the facets that connects to the astragalus can be seen (Figure 6).

Metatarsals: Specimen 1912-V, refers to metatarsus III fused to the right metatarsus IV (Figure 6), providing important information about the ontogeny of the individual, indicating the possibility of an adult animal, which is confirmed by the measurements shown and compared with other specimens (Table 2). In dorsal view it is possible to see the features of the bone, however, in plantar view, the specimen is well deteriorated. In the proximal view, metatarsal III has a concave joint that fits into the distal region of the ectocuneiform. On the lateral side, we find the suture sign and total fusion with metatarsal IV. Metatarsus IV is whole when viewed dorsally. The plantar view shows signs of abrasion and weathering. In its proximal-lateral region, it articulates with the cuboid. On the opposite side, in the proximal-medial region, it contacts both the ectocuneiform and metatarsal III.

Navicular: The right navicular (1911-V) is complete, showing some signs of abrasion (Figure 6). The articular facet that connects to the astragalus is in its posterior region, with the most medial part having a semi-spherical and concave shape, and the other lateral part having a more convex shape. The dorsal and plantar facets show roughness, but no articulation area. The distal portion of the navicular shows a more convex shape with two facets that connect to metatarsal II, ectocuneiform, and mesocuneiform which are fused, a diagnostic characteristic of the species. The lateral surface is a narrow strip occupied by articular facets that go to the cuboid.

Ectocuneiform: Specimen 1913-V is a right ectocuneiform (Figure 6). In the proximal view, it exhibits a circular shape with a concave face that articulates with the navicular (1911-V). In the distal view, the face becomes convex, forming an articulation with metatarsal III (1912-V). The lateral surface contacts the cuboid, while the medial surface contacts the mesocuneiform. The dorsal region is well-preserved, whereas the plantar surface exhibits signs of abrasion and weathering.

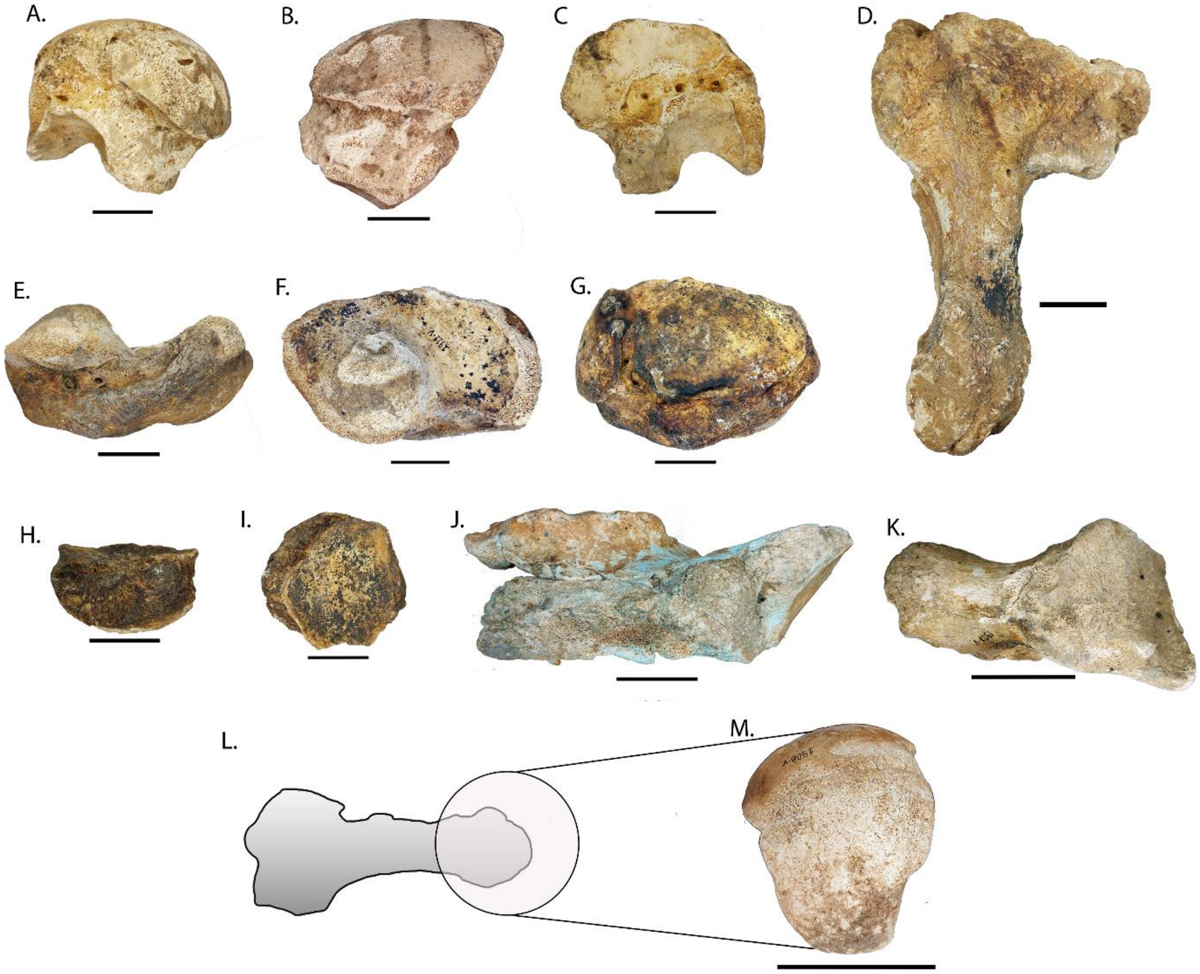


Figure 6: Appendicular elements of *Eremotherium laurillardi*. 1910-V, right lunar, **A-C**; 1912-V, right metatarsal III + IV, **D**; 1911-V, right navicular **E-G**; 1913-V, right ectocuneiform, **H-I**; 1907-V, right calcaneus, **J**; 1906-V, left calcaneus, **K**; 1908-V, humerus fragment, **L-M**. **A** and **J**, lateral view; **B**, **D**, **E** and **H**, dorsal view; **C**, medial view; **F**, **I** and **K**¸ proximal view; **L**, anterior view; **G**, **I** and **M** distal view. **A-I**, 5 cm scale. **J-M**, 10 cm scale.

Chronological and Geographical Distribution: Species known to occur in the Late Pleistocene (Cartelle, 1992; Cartelle and De Iullis, 1995). Temperate North America (TNA), Southern Mexico and Central America (SMCA), Northern South America (NSA), West Coast of South America (WCSA), Andes and Altiplano (AA), Brazilian Intertropical Region (BIR), (McDonald, 2023).

Brief Comparative Remarks: The mammals most associated with the Pleistocene Epoch are mastodons (e.g., *Notiomastodon platensis*), toxodons (e.g., *Toxodon platensis*), and giant sloths.

Among the sloths (megatherids, *Megatherium* and *Eremotherium*), the most representative species in Brazilian territory is certainly *Eremotherium laurillardi* (Cartelle, 1992; Ribeiro and Carvalho, 2009). McDonald (2023) further emphasizes the strong Pan-American representation of *Eremotherium*. In addition to *E. laurillardi* as a representative of the Megatheriidae in Brazil, Lopes and Pereira (2019) also record remains attributed to *Megatherium americanum*, which was, until now, limited to the region where the state of Rio Grande do Sul is located today.

Ground sloths, included in the Megatheriidae family, were among the largest sloths that lived in South America. *Eremotherium* could reach six meters in length, with an average weight of 2730 kg, featuring long and sturdy claws (Paula Couto, 1979; Cartelle, 2000; Barbosa et al., 2023). According to Cartelle (2000), their morphology indicated that these animals relied on the lateral edge of their feet and the lateral back of their hands for movement. Toledo et al., (2018), propose that: "*the key anatomical criterion for defining pedolaterality in metatherians is inclination of the digital plane, which can be inferred from the relative positions of the navicular and cuboid*".

In addition to some of the characteristics that differentiate *Eremotherium* from *Megatherium* such as anterior appendicular elements, which are more gracile than in *M. americanum*; the carpals show fusion of some elements (trapezoid, trapezoid, MC I and MCII); the femur, showing a flatter body in *Eremotherium*, while in *M. americanum* it shows a torsion (Cartelle, 1992; characteristic observed in the figurative femur being held by the man - Figure 7).

All the material collected for this species pertains to the post-cranial skeleton. During bone analysis and description, the articulation of certain foot bone elements became evident, including the navicular (1911-V), metatarsal III + IV (1912-V), and ectocuneiform (1913-V) (see Figure 6). We consider here that they belong to a single individual after comparisons and measurements (Table 2).

During the data collection in the region and cavities, with the GSME team, access to a photograph from the region in the mid-80s was obtained (Figure 7). Subsequently, to obtain the photograph, two pieces were donated which, upon analysis, were found to be fragments of a humerus (1908-V) of *E. laurillardi* depicted in the photograph in Figure 7. The donor of the pieces reports that the specimens were stored with little protection and exposed to the action of biotic and abiotic factors.

Most of the skeletal elements relating to this species were not found. The materials studied here show traces of direct water action, due to their exposure to the drainage zone inside the cave. It is believed that due to the arrival of residents at another time and the lack of knowledge about paleontological heritage, such as treatment, handling, and importance, a lot of information was lost. In comparison with other specimens of the species *E. laurillardi* deposited in the LIPE-SP-MHN-UFAL palaeovertebrate collection, from other paleontological sites in the state of Alagoas, they have higher proportions (Table 2), and they present the same characteristics mentioned by Cartelle (1992) and other references.

Table 2. Measurements (mm) of *Eremotherium laurillardi* postcranial bones. Abbreviations: **EDP**, dorsoplantar or dorsopalmar thickness; **CPD**, proximodistal length; **LML**, mediolateral width. (*) in this article; (1) the largest measured specimen in the SP-MHN-UFAL collection; (2) Lobo et al., (2015).

	Measurements (mm)		
Lunar	**EDP**	**CPD**	**LML**
SP-MHN-UFAL 1910-V *	138	125	100
SP-MHN-UFAL 1008-V (1)	129	112	77
LGUESB 0043 (2)	100.4	80.2	70.2
LGUESB 0049 (2)	-	76.7	80.5
Navicular			
SP-MHN-UFAL 1991-V*	115	89	174
SP-MHN-UFAL 819-V (1)	85	63	135
SP-MHN-UFAL 1200-V (1)	74	-	145
LGUESB 0035 (2)	72.3	62,3	127,8
Ectocuneiform			
SP-MHN-UFAL 1913-V*	94,4	48,4	99

Figure 7. Photograph showing megafauna bones taken from the karst region, from the Furna do Cazuza natural cavity. Font: Image provided by the Grupo Mundo Subterrâneo de Espeleologia - GMSE.

Order PILOSA Flower, 1883
Superfamily MYLODONTOIDEA Ameghino, 1889
Family SCELIDOTHERIIDAE Ameghino 1889
Subfamily SCELIDOTHERIINAE Ameghino, 1904
Genus *Catonyx* Ameghino, 1891
Catonyx cuvieri (Lund, 1839)

Material: SP-MHN-UFAL, skull (1882-V); fragment of ascending process of jugal - left side (1886-V); hyoid (1883-V); left epihyoid (1884-V); left stylohyoid (1885-V); ossified thyroid cartilage (2162-V); left m3 (1887-V); fragment of mandible (1888-V); sternal rib fragment (2188-V; 2189-V); sternebrae (2192-V; 2193-V; 2194-V; 2195-V); rib fragments (2152-V; 2153-V; 2154-V; 2155-V; 2156-V; 2157-V; 2158-V; 2159-V; 2160-V; 2161-V); left humerus (proximal portion) (2179-V); left humerus (distal portion) (2180-V); left ulna fragment (2163-V); right ulna fragment (1899-V); left (2164-V), and right cuneiform (2173-V); left (fragmented; 2187-V), and right unciform (2172-V); left (fragmented; 2186-V), and right magnum (2171-V); left (fragmented; 2185-V), and right lunar (2174-V); right trapezoid (2175-V); right pisiform (2178-V); right scaphoid (1918-V); left (2176-V) and right (2177-V) trapezium + MC I; right MC II (1894-V); left (1891-V), and right (2170-V) MC III; left (1902-V), and right (1905-V) MC IV; left (1903-V), and MC V (1893-V); right proximal phalanx of digit I (1900-V); right proximal phalanx of digit II (1895-V); left (1892-V), and right proximal phalanx of digit III (2168-V); right middle phalanx of digit II (1896-V); left (1890-V), and right middle phalanx of digit III (2169-V); right distal phalanx of digit I (1901-V); right distal phalanx of digit II (2165-V); left distal phalanx of digit III (1889-V), and right distal phalanx of digit III (2166-V); left distal phalanx of digit V (2167-V); left (1919-V) and right (1920-V) palmar sesamoid; sesamoids (1897-V and 1898-V); sesamoid of MC IV (2184-V); fragment of pelvis (acetabular fossa) (1914-V); right astragalus (2183-V); calcaneus fragment (distal portion) (2182-V); left (1916-V) and right (1917-V) patella.

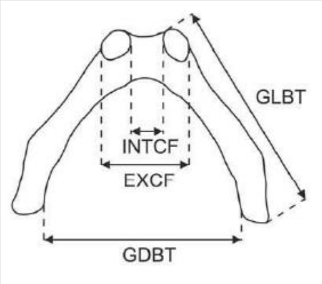
Description:

Skull: The skull 1882-V shows a transverse fracture in the line of the orbito-sphenoid, with the absence of the rostral portion. On ventral view, a straight suture is observed between the basisphenoid and basioccipital, and the occipital condyles project ventrally (Figure 8). On its left lateral face, incrustation is noted on the zygomatic process of the squamosal. A discontinuity is observed in the squamosal process, not connecting to the zygomatic arch as a single element. It is not possible to determine the morphology and description of the nasal portion and the alveolar region of tooth insertion, as the region is obliterated. The cranial sutures are mostly closed, a characteristic noted in some adult individuals. However, not all diagnostic features are present in the observed specimen. The ossicles of the middle ear, as well as the entotympanic plates (medial and lateral), are absent on both sides.

Hyoid apparatus: Parts of the hyoid apparatus (1883-V, hyoid; 1884-V, epihyoid; 1885-V, stylohyoid) and the ossified thyroid cartilage (2162-V) were found preserved (Figure 8). Specimen 1883-V refers to the fusion of the bashyoid and thyroid, this fusion is called "V-bone" (Table 3). It is possible to see the development of two prominences in the anterior region which articulate with the ceratohyoid. The ceratohyoids are absent. Like the hyoid, the ossified thyroid cartilage has a "V" shape, and the articulation facets are present in both. The thyroid cartilage (ossified) is broken, and some parts of the thinner, central region are missing.

The stylohyoid (1885-V) is complete. In its proximal portion, it shows a mid-lateral narrowing, where the articular facet that connects to the basicranium is located; towards the distal region, the body of the stylohyoid shows a cylindrical and rectilinear aspect; in the distal portion, there is the articular facet with the epihyoid. The epihyoid (1884-V) of this specimen of *Catonyx cuvieri* is smaller than the stylohyoid. It shows mediolateral compression and is wide anteroposteriorly. The bone decreases in width from proximal to distal. The facet for the stylohyoid is slightly concave, while for the ceratohyoid it is convex.

Table 3. Hyoid Apparatus Measurements (in mm). GLSTY: greatest length stylohyal; GLEPI: greatest length epihyal; GDBT: greatest distance between thyroyals; GLBT: greatest length basihyal + thyrohyal; EXCF: external width between cerathofacets; INTCF: internal width between cerathofacets. (Illustration on the right from Pérez et al. 2010)

	Measurements (mm)	
GLSTY	99.5	
GLEPI	55.6	
GDBT	65.3	
GLBT	75.4	
EXCF	34.0	
INTCF	10.8	

Tooth: Specimen 1887-V is a fragmented left m3 (Figure 8). It was the only tooth found so far and shows the cusp region preserved with breakage marks. Among the lower molars, m3 is the most striking. It shows labiolingual compression, and is three-lobed (mesial lobe, accessory or vestigial lobe, and distal lobe); the accessory lobe is located on the lingual face, it is oriented towards the innermost region of the mouth, these characteristics allow the specimen to be attributed to *Catonyx cuvieri*. The fragment of the mandible (1888-V) is only the condylar facet of the left side of the mandible, the rest is missing.

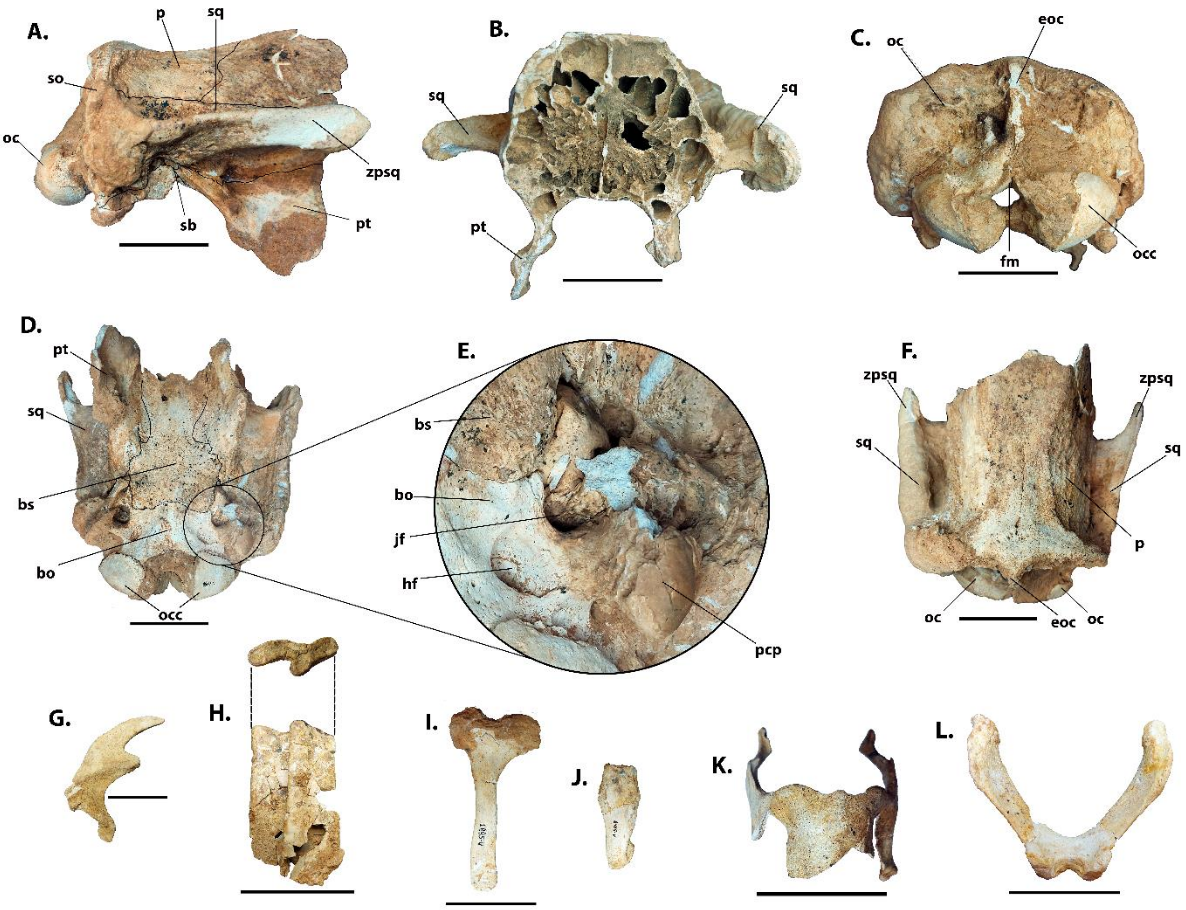


Figure 8. Cranial elements of *Catonyx cuvieri*.1882- V, skull, **A-F**; 1886-V, fragment of ascending process of jugal (left), **G**; 1887-V, left lower third molariform, **H**. Hyoid apparatus: 1885-V, left stylohyoid, **I**; 1884-V, left epioid, **J**; 2162-V, ossified hyoid cartilage, **K**; 1883-V, hyoid, **L**. **A**, **G**, **I**, **J**, lateral view; **B**, rostral view; **C**, posterior view; **D**, **E**, **K**, ventral view; **F**, dorsal view; **H**, occlusal view and vestibular view; **I**, lateral view; **L**, anterior view. Abbreviations: bo, basioccipital; bs, basisphenoid; hf, hypoglossal foramen; jf, jugular foramen; occ, occipital condyle; pcp, paracondylar process of exoccipital; oc, occipital; occ, occipital condyle; p, parietal; pt, pterygoid; sb, sutural bone; sq, squamosal. Scale: 5 cm.

Vertebrae, ribs, and sternebrae: The rib specimens found and analyzed mostly correspond to fragments, some of which correspond to the proximal portion of the articulation for the vertebrae. Specimens 2188-V and 2189-V show anteroposterior compression, two convex articulation surfaces with a separation between them, and correspond to the articulation region for the sternum. Some articulated vertebrae of the cervical and thoracic series were found; the central and lateral neural processes of the vertebrae are mostly fractured, broken, or absent, and only the vertebral bodies can be seen in sequence. The sternebrae corresponds to the portion of the sternum, has an articular surface for the ribs and only specimens 2193-V and 2194-V are whole, in the other sternum found only the posterior region is preserved.

Humerus: Specimens 2179-V and 2180-V are fragments of a left humerus, the proximal portion, and the distal region respectively. The proximal portion preserved in 2179-V refers only to a small part of the beginning of the humeral head and the greater tuberosity present on the dorsal side. In 2180-V, the preserved part of the diaphysis shows part of the capitulum and the lateral epicondyle.

Ulna: the 1899-V ulna is fragmented, with the diaphysis and distal portion missing. In the preserved portion, the coronoid processes, radial notch, trochlear notch, and olecranon are present. The specimen is elongated and straight. The specimen measures 104.66 mm, from the olecranon to the highest part of the trochlear notch; 97.60 mm, from the coronoid process to the anterior portion. The fragment of the left ulna (2181-V) also refers to the dorsal proximal portion of the bone and its entire distal and anterior portion is obliterated. Unlike 1899-V, ulna 2181-V shows a more open angulation in the trochlear region and a more developed olecranon.

Carpals

Cuneiform: specimen 2164-V, corresponding to a left cuneiform, articulates with the fragment of the articular surface of ulna 2163-V (Figure 9). Unlike the right specimen, which is complete, the entire palmar region is absent in this one, which is evident when observed in the proximal and palmar views. It is still possible to see the articulation facets for the ulna in the proximal region and for the unciform in the distal region, both showing signs of erosion.

The right cuneiform, 2173-V, has articulation faces with the lunar, pisiform, unciform, and ulna (Figure 9). The articular surface for the pisiform is partially separated from the articular surface of the ulna and is slightly flat, showing a beginning of curvature closer to the ulnar articular region. Also, in specimen 2173-V, the medial region shows a concave articular surface for the lunar, while in its distal region, the surface for the unciform is convex. Note that the articular surface for the lunar encounters the articular surface for the unciform. The medial part of the articular surface for the unciform is saddle-shaped, with a dorsopalmar convexity and a mediolateral concavity.

Lunar: Specimen 2174-V, referring to the right lunar, shows the presence of surfaces that articulate with the radius, cuneiform (2173-V), unciform (2172-V), magnum (2171-V), and scaphoid (1918-V) (Figure 9). The proximal surface is convex dorsopalmarly and connects to the radius. The articular facet with the cuneiform is concave and faces laterodistally; the dorsal part of the articular facet for the magnum shows a convexity that faces dorsopalmarly; between the articular facet with the cuneiform and the mediodistal articular facet with the magnum, there is a small concave facet that contacts the unciform. The medial articular surface for the scaphoid is slightly concave. The left lunar (2185-V) is fragmented, partially showing only two articular surfaces: one for the radius, on its most proximal surface, and an articular surface for the cuneiform on its lateral region.

Scaphoid: The right scaphoid 1918-V is intact (Figure 9). The bone has three articulation facets, one for the radius, one for the lunar, and another for the trapezoid. It has a slightly triangular shape in both proximal and distal views, with a small curvature in the more medial region; the proximal region exhibits a dorsopalmarly oriented convexity. This articular surface encounters the radius; the scaphoid displays a concave lateral base, where the more dorsal region has a semilunar shape. In this region, the articular surface for the lunar is located; the medial base is convex; in the distal view, a concave facet for the magnum bone is observed, divided into two. They are separated from each other and arranged dorsopalmarly in sequence, making contact with the articular facet for the lunar.

Trapezoid: 2175-V is complete, showing only a small break in its distal face; this face articulates with metacarpal II (1894-V) (Figure 9). The specimen is flattened proximodistally and in its proximal region is located the articular facet for the scaphoid (1918-V), showing a slight convexity. When seen in proximal view, the specimen has an inverted "L" shape. The medial border is lower and has a greater dorsopalmar depth (39.0 mm) than the more lateral border (18.5 mm). The lateral face faces the magnum while the medial face faces metacarpal I. In 2175-V, the articular surface for metacarpal II is concave palmarly and convex dorsally and exhibits facets with different orientations.

Magnum: Specimen 2171-V is complete and refers to the right magnum. This bone is in the center of the carpus (Figure 9), with articulation facets for the lunar in the proximal region; unciform in the lateral region; MC III in the distal region; scaphoid in the proximomedial region; trapezoid in the medial region; and the MC II in the mediodistal region. The magnum has a concavity in the articular facet for the lunar and a dorsopalmar convexity in the palmar portion of the facet for the scaphoid. The palmar region of the articular surface for MC III is convex mediolaterally. The articular facet for the unciform is elongated and concave dorsopalmarly, narrow proximodistally, and does not contact the articular surface for MC III. In contrast to the right specimen, the left magnum (2186-V), has its proximal portion eroded and it is not possible to see the articular facet for the lunar, showing only the distal articular facet and partially the articular facet for the unciform.

Unciform: Situated between the magnum, the cuneiform, and the MC III, MC IV, and MC V, the unciform has a dorsopalmar concavity with a slightly oblique orientation and mediolateral convexity when seen in proximal view (Figure 9). In the right unciform (2172-V), the articular facet for the cuneiform is elongated dorsopalmarly and occupies most of the proximal surface; located in the dorsomedial region is the articular facet for the lunar, this separates the articular surfaces of the cuneiform and the magnum, this separation is also evident when observed in dorsal view; in the medial region of the unciform with a slightly flat feature is the articular surface for the magnum.

The distal region of the unciform has three areas of contact with the metacarpals. More medially there is the surface for MC III, showing the largest articular face between the metacarpals; in the center, there is the facet for MC IV, showing a slight convexity; and more laterally and of smaller size, there is the surface for MC IV, also showing a slight convexity. The left unciform (2187-V) is deteriorated and only the dorsal surface and part of the articular facet for the cuneiform on the proximal surface can be identified.

Pisiform: 2178-V is shaped like a walnut. The specimen is whole with only a slight sign of abrasion on its articular facet (Figure 9). This bone has a single articular surface for the cuneiform, in a slightly circular and flat shape.

Trapezium-Metacarpal I: Specimens 2176-V and 2177-V are complete and correspond to the trapezoid + MC I (Figure 9). They have a slightly triangular inverted "L" shape. It articulates proximally with the scaphoid through an elongated, concave facet; it connects with MC II through an almost triangular lateral surface, with a distal apex that is slightly flat; and it exhibits a convex structure in its distal region.

Metacarpals

Metacarpal II: MC II (1894-V) is fragmented and only the mesodistal portion can be analyzed (Figure 9). On the distal surface, the presence of the carina can be seen on the midline, developed in a dorsopalmar direction and with lateromedial convexity. A small recent break can also be seen on the palmar surface.

Metacarpal III: The right MC III (2170-V) is wider mediolaterally in the proximal region and reduces its width as it approaches the distal region. The right MC III articulates proximally with the magnum (2171-V) and the unciform (2172-V), proximomedially with the trapezoid, and laterally with MC IV (1905-V) (Figure 9). The articular surface for the magnum is distributed dorsopalmarly, has a concave shape in its most dorsal and palmar portions, and a slightly convex shape in the most central region; the articular facet for MC IV (1905-V) occupies the most proximal region of the lateral surface; the palmar surface is concave proximodistally; and the proximodistal length is greater on the lateral side of the carina.

Unlike the right, the left MC III (1891-V) is fragmented. Its plantar and medial facets are absent; however, it is still possible to identify the lateral articular facet for MC IV, the articular facet for the unciform, part of the articular facet for the magnum and a fragment of the articular facet for the trapezoid. In its distal region, the carina that connects to the proximal phalanx is still present (1892-V).

Metacarpal IV: The right MC IV specimen (1905-V) shows fragmentation on its dorsal surface, which is more intense in the proximal region. On the proximal surface is the articular facet for the unciform, showing a dorsopalmarly sinuous feature, initially concave on the dorsal portion, and convex on the plantar region; on the proximomedial surface, the facet for MC III (2170-V) has a slightly convex aspect; and on the lateral face, a concave facet for MC V. It is also possible to notice that there has been a loss of the dorsal surface in its most distal region. The plantar view shows a small ridge near the articular surface for MC III and part of the carina that articulates with the proximal phalanx in the distal region of the bone.

The left MC IV (1902-V) shows a greater degree of abrasion on its dorsal face than the right, and it is not possible to see the features of this face. This specimen shows greater dorsopalmar depth in the proximal region than in the distal region. The articulation faces for MC III on the medial side, for MC V on the lateral side, and for the unciform on the proximal side are still preserved.

Metacarpal IV: Located in the most lateral region among the metacarpals, MC V has few areas of articulation. The right specimen (1983-V) shows a convex articular facet for the unciform in the proximal region (Figure 9). Contacting it medially is the facet for MC IV, with a flat-to-concave feature. Analyzing the left MC V (1903-V) we see: a small break in the dorsal surface in the mesoproximal region; the articular facet for MC IV is incomplete; in plantar view, there are signs of erosion and breaks in the proximal and distal regions.

Phalanges

Most of the phalanges found (proximal, middle, and distal) are fragmented.

Digit I: Specimens 1900-V and 1901-V are articulated and complete (Figure 9). The proximal phalanx (1900-V) shows a concavity on its articular face towards the trapezium + MC I; in its distal region, a groove can be seen running from the dorsal to the palmar region, passing through the articular trochlea of the distal phalanx (ungueal); the specimen referring to finger I is the smallest among the fingers of *C. cuvieri*. On the distal phalanx (1901-V), a lateral view shows that the articular structure for the proximal phalanx has a hook-like appearance. This projection contacts the groove present on the dorsal surface of the proximal phalanx (1900-V). The articular surface shows two concavities separated by a small sagittal crest, this facet is better observed in the proximal and plantar views. In lateral view, the dorsal region shows a curvature and tapers towards its apex, while in the plantar region, it is flatter and more rectilinear.

Digit II: The phalanges of digit II follow the sequence after the distal region of right MC II (1984-V). Only the right proximal (1895-V) and middle (1896-V) phalanges are complete (Figure 9). Specimen 1895-V is short proximodistally and in proximal view shows a dorsolpalmar groove which marks the limit to the articular carina of metacarpal II. Specimen 1896-V shows a width between the articular condyles that is slightly smaller than the proximal end. The ungueal phalanx of digit II (2165-V) is incomplete and shows signs of abrasion, with only the proximal articular region, the plantar base, and the initial part of the dorsal region.

Digit III: The specimens corresponding to the third digit, right and left, are fragmented, and show only a few characteristics that made identification possible. On the right proximal phalanx (2168-V), only the dorsal region and the proximal region are partially preserved. 2168-V is short proximodistally and the articular region for the metacarpal carina is visible. On the left proximal phalanx (1892-V), part of the lateral region, the dorsal region, and the articulation facets of the most lateral region for MC III (1891-V) and the middle phalanx were preserved.

The right middle phalanx (2169-V) has much of its surface obliterated, but it is still possible to see the presence of the most proximal plantar region, as well as a small part of the articular facet for the proximal phalanx in the most posterior region. The left middle phalanx (1890-V) is more complete than the right; the articular facet of the most lateral region of the proximal surface, the laterodistal condyle and part of the sagittal sulcus can be seen.

The distal phalanges are incomplete. The right distal phalanx (2166-V) has only the most proximal region preserved; one of the two concave surfaces that connect with the distal condyle of the medial phalanx is present. The left nail phalanx (1869-V) shows the lateral surface and distal region well preserved, with part of the ungueal cap still present; a curvature in the dorsal region and more rectilinear in the plantar region; the proximal articular portion is absent.

Digit V: specimen 2167-V is complete, slightly oval, has a unique concave articular facet for the left MC V (1905-V), and a proximodistally convex abaxial surface.

Sesamoids: both plantar sesamoids (right 1920-V and left 1919-V) found are dorsopalmarly flattened and almost rectangular in shape (Figure 9). Specimen 1919-V has one region missing compared to 1920-V. The sesamoid of MC IV (2184-V) refers to the sesamoid of the palmar region of MC IV, it is longer proximodistally than laterally, has a sickle shape and the signs of abrasion present do not allow detailed visualization of the articular face.

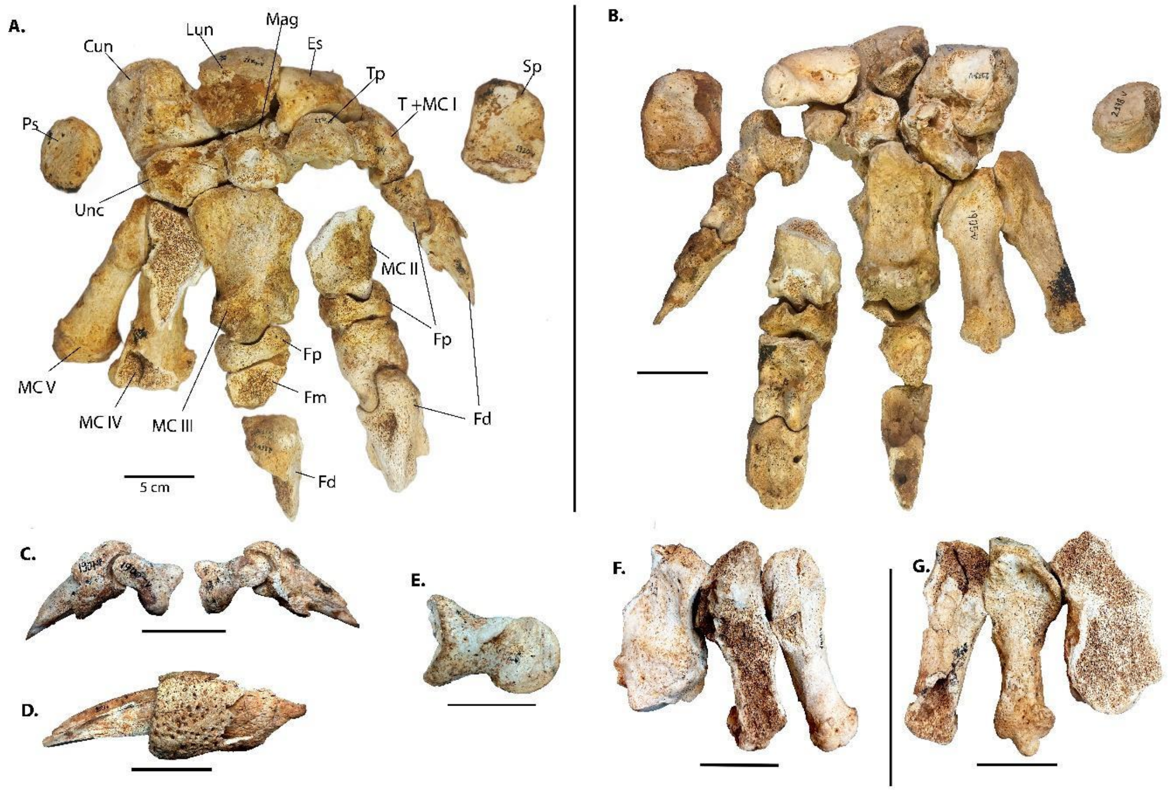


Figure 9. Elements of the right hand of *Catonyx cuvieri*. Right hand, **A-B**. 1900-V, middle phalanx and 1901-V, distal phalanx of digit I, **C**; 1889-V, distal phalanx of left digit II, **D**; 1896-V, medial phalanx of digit II, **E**; left hand: 1891-V, MC III; 1902-V, MC IV; 1903-V, **F-G**. **A** and **F**, dorsal view; **B** and **G**. palmar view; **C**, medial and lateral view; **D-E**, lateral view. Abbreviations: **Unc**, unciform; **Ps**, pisiform; **Cun**, cuneiform; **Lun**, lunar; **Mag**, magnum; **Es**, scaphoid; **Tp**, trapezoid; **T+MC I**, trapezoid plus metacarpal I; **Sp**, palmar sesamoid; **MC**, metacarpals; **Fp**, proximal phalanx; **Fm**, middle phalanx; **Fd**, distal phalanx. Scale: 5 cm.

Astragalus and Calcaneus: The right astragalus (2183-V) is complete and shows the typical morphology of the bone, with its articular facets for the tibia-fibula, cuboid, navicular, and calcaneus (Figure 10). The medial and lateral trochlear surfaces are modified compared to other Scelidotheriidae, forming an elevated and globose odontoid process and a discoid, horizontal, and semicircular facet. The angle formed between the odontoid process and the discoid facet is obtuse (characteristic of *Catonyx cuvieri*). The articular facet for the cuboid is concave, a diagnostic feature for the Scelidotheriinae (Miño-Boilini, 2012). Specimen 2182-V, on the other hand, refers to a fragment of the calcaneus identified only as part of the calcaneal tubercle.

Patellae: The patellae (1916-V and 1917-V) have an elongated concavity proximodistally, and the bone is more robust at the base than at the apex. In dorsal view, there is a slight lateromedial curvature, which is more evident after the midline of the bone; in the anterior region, located more proximally, there is the articular face for the femur (Figure 10). When compared to each other, the left patella (1916-V) differs due to the high degree of abrasion noted on its entire surface.

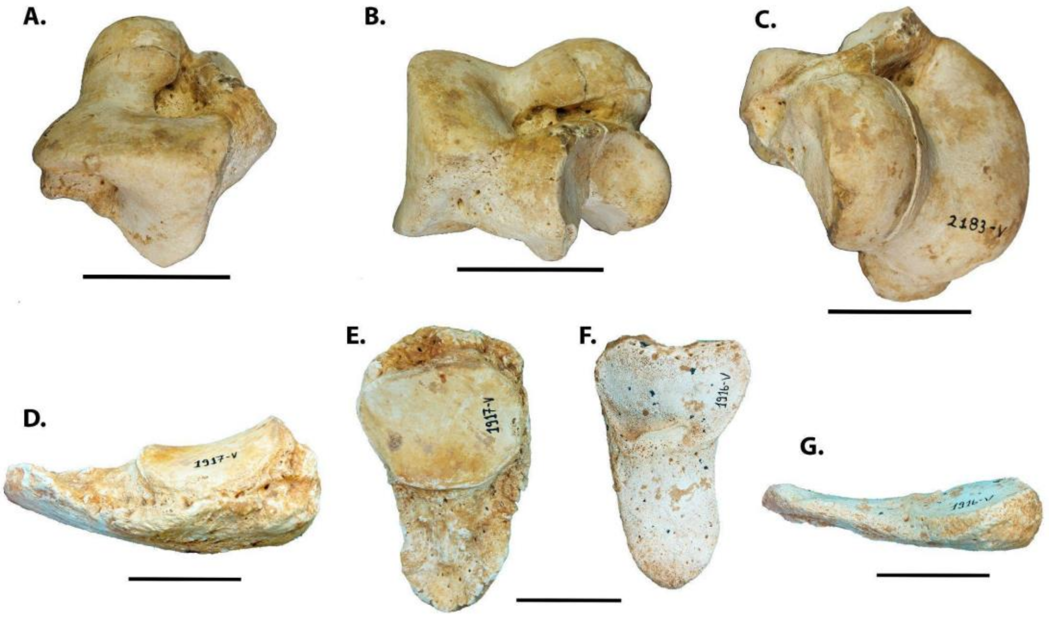


Figure 10. Posterior elements of *Catonyx cuvieri*. 2183-V, Astragalus, **A**-**C**. 1917-V, right patella, **D**-**E**; 1916-V, left patella; **A**, dorsal view; **B**, anterior view; **C** and **D**, lateral views; **G**, medial view. Scale: 5 cm

Chronological and Geographical Distribution: *Catonyx cuvieri* was distributed within the Pleistocene (Cartelle et al., 2009; McDonald, 2023), and was initially considered an endemic species of Brazil with records for Rio Grande do Sul, Paraná, Minas Gerais, São Paulo, Bahia, Piauí, Alagoas, Paraíba, Sergipe and Ceará, however, remains of the species have been found in Uruguay (Cartelle, 1992; Born et al., 2003; Pereira and Oliveira, 2003; Guerin and Faure, 2004; Sedor et al., 2004; Dantas et al., 2005; Cartelle et al., 2009; Lopes and Pereira, 2010, Corona et al., 2013, Oliveira et al., 2017) and reports of other occurrences in other locations (without official publication).

Brief Comparative Remarks: Through the valuable revisions carried out by Cartelle et al., (2009), Corona et al., (2013), and Miño-Boilini et al., (2019), it became possible to recognize three genera of Scelidotheriinae - *Scelidotherium*, *Valgipes,* and *Catonyx* - that inhabited South America during the Quaternary period.

The skull and mandible are among the most diagnostic elements for the subfamily Scelidotheriinae. Corona et al. (2013), list three diagnostic characters present in the skull of *Catonyx*: a straight suture between the basisphenoid and the basioccipital; absence of palatal grooves, and the pre-dental region of the skull and mandible longer than the alveolar length. However, only one is seen in specimen 1882-V: the suture line between the basisphenoid and the basioccipital (Figure 8). The softer features of the 1882-V skull are more like those of *C. cuvieri* and are thus distinct from *C. tarijensis*, where the temporal crests and sagittal crest are much more developed and more evident (Miño-Boilini, 2016).

Some characteristics such as the orbital portion of the lacrimal, in *Catonyx* is more expanded than the facial, while in *Scelidotherium* the two portions are equal in size (Gaudin, 2004). In *C. cuvieri*, the rostral region is narrower than in *C. tarijensis* or *C. chiliensis* (Corona et al. 2013). Unfortunately, this cannot be observed in specimen 1882-V, due to the absence of the region. A discontinuity in the squamosal process of the arch is noticeable, so the zygomatic arch does not close into a single element, as occurs in *E. laurillardi* (Naples and Mcafee, 2012). The suture lines are not completely fused, a feature observed in animals of a less advanced ontogenetic stage (Figure 8).

The teeth of the Scelidotheriinae are compressed in a buccal-lingual direction, the upper molariforms in occlusal view can vary from subtriangular (e.g. *Catonyx* and *Valgipes*) to suboval (e.g. *Scelidotherium*) (Carlini and Scillato-Yané, 2004). Teeth isolated from *Valgipes* and *Catonyx* show morphological similarities, which makes it difficult to distinguish between them (Cartelle et al., 2009). However, the material studied here was articulated with the other elements described in the paper, which made it possible to identify it as *C. cuvieri*. The teeth of *Catonyx* are large in proportion to the size of the skull compared to *Scelidotherium* (Nieto et al., 2021). The molariform found (m3) 1887-V, was attached to the lateral portion of the skull in the squamosal process, next to it was the fragment of the ascending process of the jugal (1886-V).

Among the elements that make up the hyoid apparatus, Casali and Perini (2017) describe that the hyoid bone of Xenarthra has a general structure made up of a "V" shaped bone (basihyoid fused with the thyrohyoid) and three bones in pairs (stylohyoid, epihyoid and ceratohyoid), which are separated in most taxa. The "V" shaped hyoid is observed in specimen 1883-V, attributed to *C. cuvieri*, this feature differs in *Glossotherium* and *Paramylodon*, representatives of the subfamily Mylodontinae, where the hyoid has a similar "U" shape (Pérez et al., 2010).

Specimen 1899-V resembles the ulna of *C. cuvieri*, studied and analyzed by Cartelle et al (2009) and Miño-Boiloni (2012), where the specimen is more elongated, straight, and less robust, unlike *Scelidotherium, C. tarijensis* and *C. chiliensis*.

Scelidotheres have pentadactyl hands, characterized by the absence of ungual phalanges on fingers III and IV in *Scelidotherium* and on fingers IV and V in *Valgipes* and *Catonyx*. The hand of *Catonyx* has several features similar to *Scelidotherium* but does not share these characteristics with *Valgipes* (Miño-Boilini, 2012). Corroborating what was described in the analyses carried out by Cartelle et al. (2009), the ungual phalanges two and three of *Catonyx* are similar in size, wide, and not curved, unlike those described for *V. bucklandi*, which are narrow and curved.

The proportion between the proximodistal height of the lateral side of the cuneiform and the width of the ulnar facet is one of the morphological aspects that can be used to distinguish species of *Scelidotherium* Owen, 1839 and other related genera, such as *Catonyx* and *Valgipes* Gervais, 1874 (Nieto et al., 2021). The articular surfaces with the ulna and pisiform may or may not be connected in *Catonyx* (Winge, 1915), while in specimens of *Scelidotherium* described by Nieto et al. (2021), they may be separated by a slightly rough surface.

The lunar (2174-V) shows some small carbonate encrustations and some signs of recent breakage from the preparation process. The articular surfaces of the scaphoid in *C. cuvieri* are much closer together or in contact as seen in 1918-V, while in *Scelidotherium* and *Valgipes* the non-articular interval is evident on the dorsal face separating the proximal and distal articular surfaces (Winge, 1915; Nieto et al. 2021).

In the scaphoid (1918-V), the articular surfaces, proximal and distal, are in contact, a characteristic that differs in *Scelidotherium*, where a clear separation between these articular facets is evident dorsally (Winge, 1915; Nieto et al., 2021).

The magnum and trapezoid bones collected in this study are separate (non-fused), providing ontogenetic information about the specimen. This is not the case in some specimens of *Scelidotherium* studied by Nieto et al. (2021) and *Catonyx cuvieri* by Winge, (1915), where both bones are fused. The authors mention a slightly triangular shape for the trapezoid of *Scelidotherium* when viewed dorsally. In specimen 2175-V of *C. cuvieri*, an angulation closer to 90° is noted, formed by the palmar process and the dorsal region of the bone. The breaks present in specimen 2171-V are accidental and come from the preparation process. Cartelle et al. (2009) observed that the scaphoid and the magnum encounter the MC III through a single articulation in *C. cuvieri*, while in *V. bucklandi* there is a separation between the articular surfaces.

The unciform (2172-V) of *C. cuvieri* analyzed has a shape like a slightly inclined parallelogram when observed in proximal view. This feature was also observed in specimens of *Scelidotherium* analyzed by Nieto et al (2021). The articular facets for MC III, analyzed in 2172-V, are slightly flat and differ from the more concave feature found in *V. bucklandi* (Winge, 1915), and the saddle features in *Scelidotherium* (Nieto et al. 2021).

Astragalus 2183-V, follows the determining characteristic in representatives of the subfamily Scelidotheriinae, having the articular surface for the cuboid and navicular deeply concave as shown in Miño-Boilini (2012) and discussed in Cartelle et al., (2009). The angle formed between the odontoid process and the discoid facet varies little between genera (see plank 11, Miño-Boilini, 2012), based on this, it is possible to note that the astragalus of *C. cuvieri* and *V. bucklandi* exhibit this more closed angulation than in *S. leptocephalum* Owen, 1839, *C. tarijensis* (Gervais and Ameghino, 1880) and *C. chiliensis.* According to Miño-Boilini (2012), there is a variation in the angle between the discoid facet and the odontoid process, with species: *C. cuvieri* and *V. bucklandi* showing an angle of 110°, a detail observed in the specimen studied here (2183-V); *C. tarijensis* and *C. chiliensis,* 130°; and *S. leptocephalum*, ranging from 150° to 160°.

Order PILOSA Flower, 1883

Family MYLODONTIDAE Ameghino,1889

Indet.

Material: SP-MHN-UFAL, fragment of the left ulna (2181-V)

Description: The fragment of the left ulna (2181-V) refers to the dorsal proximal portion of the bone and its entire distal and anterior portion is obliterated. Unlike 1899-V, ulna 2181-V shows more open angulation in the trochlear region and a more developed olecranon.

5.2 Taxonomic, paleozoo-geographic and paleoenvironmental aspects

Initially, the Brazilian Intertropical Region - RIB was considered a paleozoogeographic region characterized by the presence of large mammals that lived in a savanna environment during the Pleistocene (Cartelle, 1999). However, more recent studies indicate a mosaic environment during the Pleistocene in the RIB, with variations in vegetation, including dry forests, cerrado, and fragments of more closed forests than the current African savannas (Dantas et al., 2020; Dantas et al., 2021; Faria et al., 2021; Lessa et al., 2021; Leoni et al., 2023; França et al., 2023).

Considering the extensive record of Xenarthra throughout the history of Brazilian paleontology (Paula Couto, 1954, 1979; Silva, 2008; Cartelle, 2012; Ghilardi et al., 2011; Oliveira et al., 2017; Andrade, 2019; Nascimento, 2020), the information presented here regarding the occurrence of the families Pampatheriidae (*Holmesina* sp.), Megatheriidae (*Eremotherium laurillardi*), and confirmation of Mylodontidae (*Catonyx cuvieri*) in Furna do Cazuza strengthens the richness of Pleistocene species diversity found in the caves of the municipality of Paripiranga.

After several decades of being considered as belonging to the subfamily Dasypodidaae (Hoffestter, 1958; Scillato-Yané, 1980), the pampateriids were recognized as a new family after the work carried out by Edmund (1985, 1987). Edmund's (1996) major contribution to the revision was clarifying the validity of the two genera: *Pampatherium* and *Holmesina*, for South America, as well as distinguishing the characteristics of the osteoderms of the two species. Pampatheriids that lived during the Quaternary in South America are recorded from Argentina, Brazil, Bolivia, Colombia, Ecuador, Paraguay, Peru, Venezuela, and Uruguay (Góis et al., 2012).

According to De Iullis et al., (2000) and Scillato-Yané et al., (2005), *Holmesina paulacoutoi* would have a diet based on softer vegetation, being herbivorous-onivorous, grazing animals. Isotopic data from species found in Bahia and other regions of the RIB point to a diet of C4 plants, making it a more generalist species (Dantas and Santos, 2020; Lessa et al., 2021). Hoffstetter (1952, apud Scillato-Yané, 2005) presents in his study the association of another species of *H. occidentalis* with megafauna animals such as *Equus (Amerhippus), Palaeolama,* and *Odocoileus,* which inhabited relatively open environments. This faunal association is like the records of the fauna that inhabited the region of Paripiranga, Bahia, documented by Nascimento et al. (2020), for the Borboletas Cave, which found the presence of *Palaeolama major, Mazama gouazoubira* and *Hippidion principale,* among others.

Giant sloths (Xenarthra) are amongst the most representative mammals in the Cenozoic fauna of South America, especially in the Brazilian intertropical region (RIB) (Cartelle, 1999). Four families with nine species are recognized for the Pleistocene of the RIB: Megatheriidae (*Eremotherium laurillardi* Lund, 1842), Mylodontidae (subfamily Scelidotheriinae - *Scelidotherium*, *Catonyx* and *Valgipes* and subfamily Mylodontinae - *Mylodonopsis ibseni* Cartelle 1991, *Glossotherium* sp. Owen 1839 and *Ocnotherium giganteum* Lund 1839)), Nothrotheriidae (*Nothrotherium maquinense* (Lund) Lydekker 1889), and Megalonychidae (*Ahytherium aureum* Cartelle et al. 2008 and *Australonyx aquae* De Iullis et al. 2009) (Corona et al, 2013; Oliveira and Cordeiro, 2017; Barbosa et al, 2023).

Although records of the Megatheriinae species, *Eremotherium laurillardi* are abundant, with a Pan-American distribution (*sensu* Cartelle and De Iuliis, 1995, 2006), we noticed one more occurrence for the species in Bahia. Two other species of the genus are still recognized, but they only occur in the United States, *E. eomigrans* De Iuliis and Cartelle, 1999 and in Bolivia, *E. sefvei* De Iuliis and St-André, 1997 (De Iuliis and St-André, 1997 and De Iuliis and Cartelle, 1999). The specimens found in the Furna do Cazuza underground cavity, in Paripiranga, Bahia, are larger than those also safeguarded in the Museu de História Natural da Universidade Federal de Alagoas, Brazil, analyzed and studied by Silva (2008), Asakura et al., (2016) and Nascimento et al., (2018) found in paleontological sites (ponds, lagoons and riverbeds) in the state of Alagoas.

The studies conducted by Cartelle and Bohórquez (1982) and Cartelle and De Iuliis (1995), involving a significant quantity of material from *Eremotherium laurillardi*, enabled the identification of intra-specific variations in morphological traits characteristic of each species (sexual dimorphism). The majority of the material analyzed in the present study consists of post-cranial elements, making it impossible to distinguish sexual dimorphism. However, in addition to the larger size of the specimens compared to some collections (e.g., like that of SP-MHN-UFAL), the presence of fused elements is observed, a characteristic commonly associated with individuals in more advanced ontogenetic stages.

Many studies related to the species can be found in the literature, and recently several other studies on the RIB have been intensified, dealing with its morphology, taxonomy, body mass, chewing apparatus, diet and isotopic analysis (Dantas, 2022). The compilation and interpretation of this data makes it possible to infer that these animals had a mixed diet (De Iullis and Cartelle, 1994; Cartelle and De Iuliis, 2006, Oliveira et al., 2020; Asevedo et al., 2021; Lopes et al., 2021; Omena et al., 2021; Dantas, 2022).

Endemic to South America, the Scelidotheriinae did not participate in the great American biotic exchange, even though they have a wide geographical distribution (Corona et al., 2013; Lobato et al., 2021). Discussions about the systematics of the subfamily and which representatives would have occurred during the Quaternary permeate the history of the group (McDonald and Perea, 2002; Miño-Boilini and Carlini, 2009; Cartelle et al., 2009; Miño-Boilini, 2012; Corona et al. 2013; Miño-Boilini et al., 2019; Casali et al., 2022).

According to Miño-Boilini and Carlini (2009) and Miño-Boilini et al. (2019), *Scelidotherium* Owen, 1839, *Valgipes* Gervais, 1873, *Scelidodon* Ameghino, 1881 and *Catonyx* Ameghino, 1891 are recognized as Quaternary genera. Later, Corona et al. (2013) considered only three genera, *Scelidotherium*, *Catonyx* and *Valgipes*. The species of *Scelidodon tarijensis* and *Scelidodon chiliensis* are now considered *C. tarijensis* and *C. chiliensis*. Cartelle et al. (2009) consider only two genera for the Quaternary of Brazil, *C. cuvieri* and *V. bucklandi*. In the study by Oliveira and Cordeiro (2017), in addition to specimens identified as belonging to *C. cuvieri* and *V. bucklandi*, a molariform was attributed to *Scelidotherium*. However, due to uncertainties about the identification of the tooth, we did not consider the occurrence of the genus, keeping only *C. cuvieri* and *V. bucklandi* as representatives of the subfamily in the Quaternary of Brazil.

This study presents the largest number of bones of *Catonyx cuvieri* attributed to a single individual in a cave among 81 registered in Paripiranga, Bahia. The species was found partially articulated and cemented by calcite; a large part of the upper region was identified and removed from the interior of Furna do Cazuza. Noteworthy findings include a fragmented cranium (mostly occipital region), fragile neck elements such as bones of the hyoid apparatus, partially fragmented ossified thyroid cartilage, articulated vertebrae, and the almost entirely articulated right hand.

We believe that elements from the lower region were taken from Furna do Cazuza, together with other elements of *Eremotherium laurillardi*. This was observed when analyzing old photos (Figure 7), where some elements such as tibias and fibulas are seen next to the femurs of *E. laurillardi*, with similar proportions and anatomy to *C. cuvieri*.

In the most recent study conducted in the Paripiranga region, Bahia, at the Borboletas cave, Nascimento et al. (2020) established the first correlations and inferences regarding the paleoecology of the region during the late Pleistocene-Holocene transition. This study documented the presence of cranial and post-cranial elements of six species distributed across ten families: Camelidae, *Palaeolama major*, Cervidae, *Mazama gouazoubira*, Toxodontidae, *Toxodon platensis*, Felidae, *Smilodon populator*, Tayassuidae, Glyptodontidae, Tapiridae, Erethizontidae, *Coendou* sp., Equidae, *Hippidion principale*, and Testudines. The study identified the Borboletas Cave as the richest in paleontological mammalian biodiversity in the region, featuring a diverse herbivorous fauna alongside the presence of a large predator.

However, we would emphasize that isotopic analyses of specimens from Borboletas Cave are necessary to obtain a more assertive paleoecological interpretation. Incorporating three more Pleistocene species, *Holmesina* sp., *E. laurillardi* and *C. cuvieri*, from Furna do Cazuza and inserted into the RIB, will provide new insights and significant data, as well as ongoing work.

Knowing the high diversity of species of giant sloths that lived during the Quaternary in Brazil and their paleoecological diversity, Dantas and Santos (2022) applied two methodologies: the Relative Muzzle Width Index (RMW) and occlusal surface area to nine species of sloths, including *C. cuvieri* and *E. laurillardi*.

The results obtained from both techniques suggest that *Eremotherium laurillardi* was adapted to a mixed diet (Dantas and Santos, 2022), corroborating the isotopic data and tooth microwear analysis, which suggest a mixed diet (Dantas et al., 2020; Oliveira et al., 2020; Omena et al., 2021; Lessa et al., 2021). For the Mylodontidae taxa (*C. cuvieri*), a mixed diet is also suggested, but adapted to the consumption of C4 plants, corroborating the isotopic results for the species (Dantas et al., 2020; França et al., 2023).

5. CONCLUSIONS

The natural cavity known as Furna do Cazuza, located in the Vaza Barris domain, Olhos D'Água Formation, studied here, has proved to be an important sedimentary and fossiliferous deposit, allowing the accumulation and preservation of vertebrate representatives of the Pleistocene megafauna, which is increasingly well documented and studied in the region of the municipality of Paripiranga, Bahia, Brazil.

The addition of three new taxa - *Eremotherium laurillardi*, *Holmesina* sp., and the confirmation of *Catonyx cuvieri* - to the already known paleobiodiversity of the Pleistocene fauna of this region, contributes significantly to future paleoenvironmental and paleoecological inferences. Currently, the species *C. cuvieri* (Scelidotheriidae) has the largest number of specimens attributed to a single individual, due to the articulated preservation of part of the skeleton, as well as the most preserved material found among the Paripiranga caves to date, thus pointing to Furna do Cazuza as a very promising cave. The fossil deposit analyzed shows monotypic and polyspecific associations with fauna that lived during the late Pleistocene.

Prospects for systematic research into Quaternary deposits in this region are fundamental for a deeper understanding of the Pleistocene palaeobiota, while at the same time making it possible to better characterize the geographical distribution and age of the palaeomastofauna found in the cave deposits studied.

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Supplementary data

Appendix 1. Measurements of specimens from the right hand of *Catonyx cuvieri* (mm)

ESPÉCIMES	**MEDIDAS (mm)**
Lunar (2174-V) - right	
Maximum width of the dorsal part of the articular surface for the radius.	63.5
Dorsopalmar depth from the articular surface to the radius.	54.5
Cuneiform (2173-V) - right)	
Maximum width of the ulnar facet measured parallel to the longitudinal axis of the facet for the unciform.	55
Maximum proximodistal height of the cuneiform on the lateral side.	49.8
Maximum mediolateral width of the ulnar facet of the cuneiform measured parallel to the palmar surface.	48.6
Pisiform (2178-V) - right	
Maximum diameter along the main shaft.	47.7
Diameter perpendicular to the main axis.	42.1
Greater dorsopalmar depth.	28.9
Magnum (2171-V) - right	
Widest dorsal surface width.	33.6
Maximum depth.	57.3
Unciform (2172-V) - right	
Larger transverse diameter across the dorsal side.	58.4
Greater craniocaudal length.	49.7

Greater dorsopalmar depth.	55.6
Greater mediolateral width.	66.6
Scaphoid (1918-V) - right	
Proximodistal length along medial edge	24.3
Proximodistal length along lateral edge	42.4
Widest width of dorsal surface	69
Dorsopalmar depth of medial extremity	30
Dorsopalmar depth of lateral extremity	46.2
Mediolateral width	64.6
Trapezoid (2175-V) - right	
Greater width of the dorsal surface	45.7
Proximodistal length of dorsal surface	25.5
Proximodistal length of palmar surface	23.1
Dorsopalmar depth of medial extremity	39
Dorsopalmar depth of lateral extremity	18.5
MC II right (1894-V)	
Mediolateral width of distal extremity	43.8
Dorsopalmar depth of distal extremity	45.3
Digit II proximal phalanx (1895-V) - right	
Mediolateral width of palmar surface	46.3
Mediolateral width of dorsal surface	38.5
Trochlea width	12
Width of distal extremity	34.4
Proximodistal length of dorsal surface	34.8
Proximodistal length of palmar surface	33
Greater longitudinal length (center-middle)	28.5

Digit II middle phalanx - (1896-V)	
Mediolateral width of proximal extremity	40.9
Mediolateral width of distal extremity	31.3
Proximodistal length of dorsal surface	64.2
Greater longitudinal length (center-middle)	61
Proximodistal length of palmar surface	33
Digit II distal phalanx - (2165-V) right	
Base height - dorsopalmar depth	44
MC III right - (2170-V)	
Maximum proximodistal length	103
Proximal width of dorsal surface	72.2
Width of the articular facet for the palmar surface magnum	22.4
Greater dorsopalmar depth of the proximal surface	60.8
Distal width	50.5
Digit III proximal phalanx (2168-V) right	
Mediolateral width	46.8
Digit III distal phalanx (2166-V) - right	
Base height - dorsopalmar depth	48
MC IV right (1905-V)	
Length	125
Proximal width	42.6
Distal width	35.2
Distal depth	45.7
MC V right (1893-V)	
Length	124

Proximal width	33
Distal width	—
Distal depth	37.4
Palmar sesamoid (1920-V) - right	
Length	65.7
Width	53.3
Depth	10.5
Palmar sesamoid (1919-V) – left	
Width	53.6
Depth	10.6

Caption list

Figure 1. Map showing the Brazilian Intertropical Region (BIR; represented by the dotted line; sensu Cartelle 1999 expanded by Oliveira et al., 2017).

Figure 2. Location map of Furna do Cazuza, municipality of Paripiranga, Bahia, Brazil.

Figure 3. Topography and Collection Area in the Furna do Cazuza Cave, Paripiranga, Bahia, Brazil; **A**. Ground plan; **B**. Longitudinal profile, focusing on the entrance area of the cave; **a**. and **b**. focus of collection areas; **C**. internal photograph of the hall and other speleothems; **D**. external photograph of the sinkhole where the Furna do Cazuza cave is located at the center of the image. DJI, Pilot: Johnson Sarmento, 2021; Photography: Daniel Menin, 2019.

Figure 4. Main fossil extraction points. A. P.2 site where excavation and collection were concentrated. B. Treatment of the blocks in the laboratory. Red, axial, and cranial elements. Yellow, post-cranial elements. Adapted from the topography carried out by the Bambuí Group, MG (2020) - Location: Roça Nova. Photo: Maria Aparecida Souza, 2020.

Figure 5. *Holmesina* sp., 2190-V (right) and 2191-V (left), osteoderms, **A**; *H. paulacoutoi,* osteoderms, **B**; *H. cryptate,* osteoderms, **C** (LPP-PV-001 holotype); *P. humbolditi,* osteoderms, **D**; *Tonnicinctus mirus*, osteoderms, **E;** *H. paulacoutoi*, osteodermo, **F.** A-F, fixed osteoderm; B'-E', movable osteoderm. A. dorsal view - above and internal view - below; B-D and B'-E' dorsal view; b-d, lateral view. B and D, Osteoderms depicted in Scillato-Yané et al. (2005); C, species studied by Moura de Jesus et al., (2019); E, osteoderms analyzed by Góis et al., (2015); F, osteoderm MNRJ 3538-V, studied by Oliveira and Pereira (2009). Scale 2 cm. Abbreviations: **aas**, anterior articular surface; **af**, anterior foramina; **es**, exposed surface; **id**, intermediate portion; **lce**, longitudinal central elevation; **ld**, longitudinal depressions; **lf**, lateral foramina; **lm**, lateral margins; **me**, marginal elevation; **lp**, lateral projection; **ss**, sutural surface.

Figure 6: Appendicular elements of *Eremotherium laurillardi*. 1910-V, right lunar, **A-C**; 1912-V, right metatarsal III + IV, **D**; 1911-V, right navicular **E-G**; 1913-V, right ectocuneiform, **H-I**; 1907-V, right calcaneus, **J**; 1906-V, left calcaneus, **K**; 1908-V, humerus fragment, **L-M**. **A** and **J**, lateral view; **B**, **D**, **E** and **H**, dorsal view; **C**, medial view; **F**, **I** and **K**¸ proximal view; **L**, anterior view; **G**, **I** and **M** distal view. **A-I**, 5 cm scale. **J-M**, 10 cm scale.

Figure 7. Photograph showing megafauna bones taken from the karst region, from the Furna do Cazuza natural cavity. Font: Image provided by the Grupo Mundo Subterrâneo de Espeleologia - GMSE.

Figure 8. Cranial elements of *Catonyx cuvieri*.1882- V, skull, **A-F**; 1886-V, fragment of ascending process of jugal (left), **G**; 1887-V, left lower third molariform, **H**. Hyoid apparatus: 1885-V, left stylohyoid, **I**; 1884-V, left epioid, **J**; 2162-V, ossified hyoid cartilage, **K**; 1883-V, hyoid, **L**. **A**, **G**, **I**, **J**, lateral view; **B**, rostral view; **C**, posterior view; **D**, **E**, **K**, ventral view; **F**, dorsal view; **H**, occlusal view and vestibular view; **I**, lateral view; **L**, anterior view. Abbreviations: bo, basioccipital; bs, basisphenoid; hf, hypoglossal foramen; jf, jugular foramen; occ, occipital condyle; pcp, paracondylar process of exoccipital; oc, occipital; occ, occipital condyle; p, parietal; pt, pterygoid; sb, sutural bone; sq, squamosal. Scale: 5 cm.

Figure 9. Elements of the right hand of *Catonyx cuvieri*. Right hand, **A-B**. 1900-V, middle phalanx and 1901-V, distal phalanx of digit I, **C**; 1889-V, distal phalanx of left digit II, **D**; 1896-V, medial phalanx of digit II, **E**; left hand: 1891-V, MC III; 1902-V, MC IV; 1903-V, **F-G**. **A**

and **F**, dorsal view; **B** and **G**. palmar view; **C**, medial and lateral view; **D-E**, lateral view. Abbreviations: **Unc**, unciform; **Ps**, pisiform; **Cun**, cuneiform; **Lun**, lunar; **Mag**, magnum; **Es**, scaphoid; **Tp**, trapezoid; **T+MC I**, trapezoid plus metacarpal I; **Sp**, palmar sesamoid; **MC**, metacarpals; **Fp**, proximal phalanx; **Fm**, middle phalanx; **Fd**, distal phalanx. Scale: 5 cm.

Figure 10. Posterior elements of *Catonyx cuvieri*. 2183-V, Astragalus, **A-C**. 1917-V, right patella, **D-E**; 1916-V, left patella; **A**, dorsal view; **B**, anterior view; **C** and **D**, lateral views; **G**, medial view. Scale: 5 cm.

4.2 ARTIGO 2 - ISOTOPIC PALEOECOLOGY (δ^{13}C), CHRONOLOGY, AND PALEOENVIRONMENTAL RECONSTRUCTION (δ^{13}C, δ^{18}O) OF LATE QUATERNARY CAVE DEPOSITS FROM THE PARIPIRANGA, BAHIA, BRAZIL

Seguindo as normas da revista

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Abstract

In this article, we report the first radiocarbon (AMS) datings and stable isotope data of carbon (δ^{13}C) and oxygen (δ^{18}O) for the paleoecological reconstruction of large and medium-sized mammals found in natural cavities — Furna do Cazuza, Gruta do Bom Pastor, and Caverna das Borboletas — in northeastern Brazil (Paripiranga, Bahia, Brazil). The obtained AMS ^{14}C datings were as follows: small vertebrate 7.675-7.845 cal yr BP; *Toxodon platensis* 14.320-14.747 cal yr BP; *Catonyx cuvieri*, 17.057-17.341 cal yr BP; *Holmesina* sp., 17.706-18.159 cal yr BP; *Palaeolama major*, 35.513-36.379 cal yr BP. Species *C. cuvieri* and *P. major* inhabited low-density forest habitats, primarily feeding on C_3 plants (δ^{13}C = -13.1‰ and -12.0‰; p_iC_3 = 100-93%). *Holmesina* likely lived in a tree savannah habitat, showing a mixed diet with a preference for C_3 plants (δ^{13}C = -9.8‰; p_iC_3 = 77%), while *T. platensis* inhabited a habitat ranging from tree savannah to open savannah, with a mixed diet (δ^{13}C = -6.8‰; p_iC_3 = 56%). Overall, our data suggest a transitional habitat between low-density forests and transitional zones from tree savannah to open savannah.

Keywords: Megafauna, Carbon and oxygen isotopes, Radiocarbon dating, Diet, Paleoenvironment

1. Introduction

The record of the vertebrate fauna that lived during the Late Pleistocene is expressively presented in various types of sedimentary deposits (e.g., ponds, lagoons, rivers, caves) throughout the territory of South America (e.g., Prado et al., 1987; Cartelle, 1999; Sánchez et al., 2004). In Brazil, megafauna is commonly recorded in the Brazilian Intertropical Region (BIR; Cartelle, 1999; Oliveira et al., 2017), which was mainly occupied by dry forest environments (Caatinga and Cerrado; Dantas and Cozzuol, 2016; França et al., 2023).

Current technological advances have enabled the increasingly precise application of different methods to clarify the chronology of the Quaternary fauna. Techniques such as U-Th series (Auler et al., 2006), accelerator mass spectrometry (AMS ^{14}C; Dantas et al., 2020; Silva et al., 2023), electron spin resonance (ESR; Ribeiro et al., 2021), and optically stimulated luminescence (OSL; Andrade et al., 2023) have been successfully applied. In addition to contributing to understanding this fauna's dispersion, these data also provide notable insights into the geographical and chronological distribution, indicating that various species lived together during the Pleistocene (McDonald, 2023).

Studies on fossils of large mammals (body mass > 44kg) and mega mammals (biomass > 1000kg) over the past decades have played a crucial role in expanding knowledge about taxon diversity, diets, ecological adaptations, intra- and interspecific relationships, as well as allowing paleoenvironmental reconstructions of the habitats these animals inhabited (Cartelle, 1999; Ghilardi et al., 2011; Araújo-Júnior et al., 2017; Lopes and Pereira, 2019; Nascimento et al., 2020; Silva et al., 2023).

The extraction of biogeochemical information from bones, teeth (dentin and enamel), and fecal remains of extinct animals has been one of the most relevant tools in the investigative scope of their paleoecology (Omena et al., 2021), allowing for the identification of environmental variations, as well as temperature, humidity, and types of vegetation present in the environment (França et al., 2015).

Among the various methods employed to seek paleoenvironmental understanding and paleoecological reconstruction, we have, for example, analyses of dental calculus, micro-wear and meso-wear of teeth (Azevedo et al., 2020; Mothé et al., 2021), masticatory apparatus (Naples and McAfee, 2012; Dantas and Santos, 2022), coprolites (Marcolino et al., 2012; Jacob et al., 2024), and isotopic analyses (Carrasco et al., 2022; Silva et al., 2023).

Animals, as they feed and drink water throughout their lives, naturally imprint geochemical traces in their bones and teeth through physiological processes, both in organic (collagen) and inorganic (hydroxyapatite; $Ca_{10}[PO_4]_6[OH]_2$) components (Koch, 2007). According to Koch (2007), the use of stable isotope analyses applied to different elements (e.g., hydrogen, carbon, nitrogen, oxygen) provides access to important information.

Stable carbon isotope analysis, present in the mineralized tissue of mammals, allows understanding of dietary habits, providing feedback on photosynthetic pathways used by consumed plants (e.g., C_3 and C_4 plants). Moreover, it still provides data on digestive physiology, habitat use, and migration (Koch, 2007; Asevedo et al., 2021). Furthermore, stable oxygen isotope analysis, in addition to providing details about fauna (thermoregulation, migration, and habitat use; Koch, 2007), also enables understanding of body water presence and values, as well as climatic factors (precipitation and temperature) in their habitats (Sponheimer and Lee-Thorp 1999; Koch, 2007).

Despite several studies conducted in the last decade on the paleoecology and paleoenvironmental reconstruction of Quaternary megamammals, no chronological and paleoecological analysis has been carried out with the fossils found in the caves of Paripiranga, Bahia, Brazil. The works of Nascimento et al., (2020; Borboletas Cave) and Lima (2017; Gruta da Presa I) began in a more in-depth manner with the first chronostratigraphic and paleoecological inferences of the fossils found in the region.

However, Lima (2017) conducted dating of a Tayassuidae species, exhibiting an age of 560 (years BP) 560±20 uncalibrated (510-550 cal yr BP), considered still recent (Holocene), and Nascimento et al., (2020), indirectly performed the first chronological and paleoecological inferences of the species found in the Borboletas Cave, comparing with specific literature.

Thus, the objective of this study is: i) to present the news absolute datings of the fossils found in the karstic deposits of Paripiranga, Bahia, through ^{14}C by accelerator mass spectrometry (AMS ^{13}C), to contextualize the ages of fossil assemblages; ii) to present and discuss the isotopic data of $\delta^{13}C$ and $\delta^{18}O$ of some species found (for example, *Catonyx cuvieri*, *Toxodon platensis*, *Palaeolama major*, *Holmesina*, and a small vertebrate associated).

2. Materials and Methods

2.1. Study Area

The studied specimens come from natural cavities in the municipality of Paripiranga, Bahia, Brazil (Figure 1). It is inserted in outcrops of Neoproterozoic metasedimentary rocks from the Sergipana Fold Belt, located in the Karstic Region of the Canudos Supergroup, constituted by the Estância group and Vaza-Barris group (Silva Filho et al., 1977; Auler et al., 2001).

The natural cavities are distributed in the metacalcareous and phyllites of the Olhos D’Água Formation, belonging to the Vaza Barris Domain. This domain is also composed of the

Frei Paulo-Ribeirópolis Formation and Capitão-Palestina Formation; however, these do not present natural cavities (Uhlein et al. 2011). According to Pereira et al., (2017), four geomorphological units are defined for the Paripiranga region: Rampa de Colúvios, Planície do Rio Vaza Barris, Morros e Colinas, and Platô de Paripiranga.

When analyzing the data of cave locations provided by CECAV (2022) along with the map developed by Pereira et al., (2017), in figure 1, it is noted that the highest concentration of caves is between the *Morros e Colinas* units (e.g., Borboletas Cave, Gruta da Presa I) and the *Platô de Paripiranga* (e.g., Furna do Cazuza, Gruta do Bom Pastor).

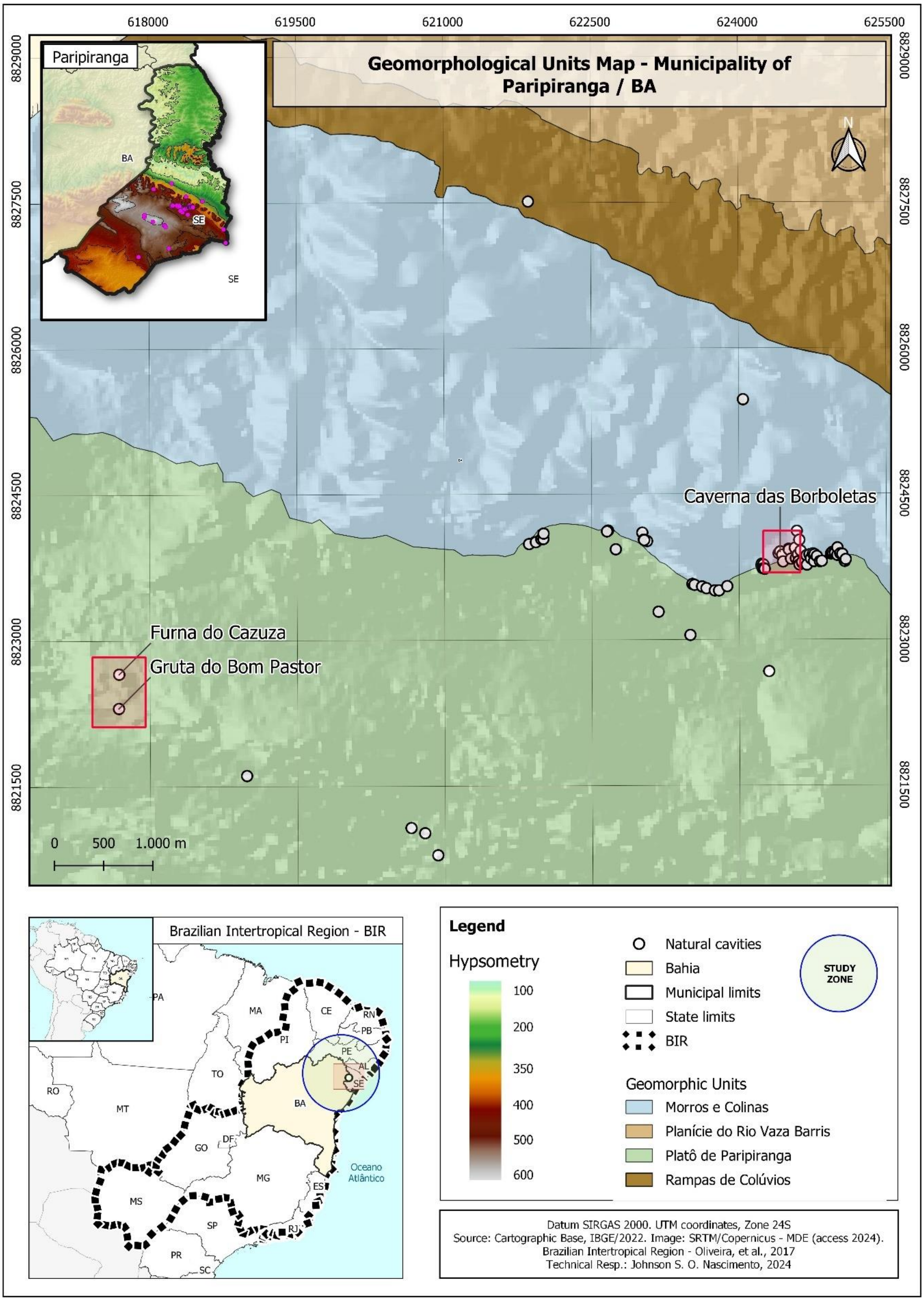

Figure 1. Map of the Geomorphological Units of the Municipality of Paripiranga, Bahia, Brazil, (Adapted from Pereira, et al., 2017)

The cave Furna do Cazuza is inserted in limestone in the geomorphological unit "*Platô de Paripiranga*". The cavity is in the center of a sinkhole and is marked by an entrance in the form of an abyss with a height of 16 meters, exhibiting inside a large hall with a vast clastic and bioclastic sedimentary deposit. Moreover, we have obtained unpublished dates for two other caves in the region: Borboletas Cave (initially studied by Nascimento et al., 2020) and the karstic environment called Gruta do Bom Pastor (only mentioned for the occurrence of megafauna by Dantas et al., 2010).

The fossil materials were found and studied by the teams of the Laboratórios Integrados de Paleontologia e Espeleologia of the Paleontology Sector of the Museu de História Natural of the Universidade Federal de Alagoas (LIPE-SP-MHN-UFAL) and by the Laboratório de Paleontologia, Departamento de Geologia, Centro de Tecnologia e Geociências of the Universidade Federal de Pernambuco (PALEOLAB-DGEO-CTG-UFPE).

2.2. Taxonomic Identification

For the taxonomic and osteological identification of *Eremotherium laurillardi* and *Catonyx cuvieri*, classifications proposed by Cartelle et al. (2009), Perez et al. (2010), Miño-Boilini (2012 and 2016), Corona et al. (2013), Cartelle et al. (2019), Boscaini et al. (2020), and Nieto et al. (2021) were followed. For Holmesina, references from Scillato-Yané (2005), Góis et al. (2012), and Moura de Jesus et al. (2019) were used. In addition, Von Den Driesch (1976) and Scherer (2009) for the Camelidae; Bond et al. (1995), Ribeiro (2003), Silva (2019) for the Toxodontidae.

We follow Cartelle (1999), and other references cited here by identifying the late Pleistocene mammals from northeastern Brazil as intertropical, *Holmesina, Eremotherium laurillardi, Catonyx cuvieri, Toxodon platensis* and *Palaeolama major.* All material presented in this article has been deposited in the collection of LIPE-SP-MHN-UFAL.

2.3. Radiocarbon (^{14}C AMS)

Radiocarbon dating was conducted on bioapatite (hydroxylapatite present in teeth and bone samples) from representatives of megafauna mammals following the technique proposed by Cherkinsky (2009). The analyzed samples correspond to specimens of *Catonyx cuvieri* (Lund, 1839), *Holmesina* Simpson, 1930 (*Holmesina* sp.), a small mammal (long bone of rodent or marsupial; Furna do Cazuza), *Toxodon platensis* Owen, 1837 (Borboletas Cave), and *Palaeolama major* (Liais, 1872) (Gruta do Bom Pastor).

The uncalibrated dates quoted were provided in radiocarbon years before 1950 (years BP), using the ^{14}C half-life of 5568 years. The error is stated as a standard deviation and reflects statistical and experimental errors. The date was corrected for isotope fractionation.

Assuming that results obtained from dating in bioapatite appear younger than those in collagen (Zazzo, 2014), a conversion of bioapatite results to collagen was used, following the equation (1) proposed by Dantas and Cherkinsky (2023). This method shows a strong correlation ($R^2 = 0.98$), a lower percentage of predicted error (%PE = 0.01), and a standard error of the estimate (%SEE = 21.83).

$$\log_{10}{}^{14}C_{collagen} = 1.09*\log_{10}{}^{14}C_{bioapatite} - 0.31 \qquad (1)$$

After the conversion, the results were calibrated to calendar ages preceding the present, maintaining the standard error obtained in $^{14}C_{bioapatite}$, using the CALIB 8.1 program (Reimer et al., 2020) and the SHCal20 curve (Hogg et al., 2020). The ages measured at 2σ are presented in Table 1.

2.4. Isotopic analysis (δC^{13} e $\delta^{18}O$)

For the determination of the isotopic composition of carbon and oxygen, samples of dental enamel from *Catonyx cuvieri*, *Palaeolama major*, *Toxodon platensis*, and samples of bone tissue from *Holmesina* sp. (osteoderm) and a small vertebrate (long bone of rodent or marsupial) were extracted. In the bone treatment process, a long bone of a small mammal was found along with sediments and seeds inside the skull of *C. cuvieri*. The analyses were conducted at the Center for Applied Isotope Studies at the University of Georgia (Georgia, USA).

The samples were processed following the methodology developed by Cherkinsky (2009). To remove the absorbed surface and secondary carbonates, the crushed bone was treated with diluted 1N acetic acid. The evolved carbon dioxide was removed from the inside of the sample fragments through periodic evacuation, allowing the action of fresh acid even on micro surfaces. After the sample was chemically clean, it was reacted under vacuum with 100% phosphoric acid to dissolve the bone mineral and release carbon dioxide (CO_2) from bioapatite.

Using the method of Vogel et al. (1984) and Cherkinsky (2009), the resulting carbon dioxide was cryogenically purified from other reaction products and catalytically converted into graphite. The ^{14}C/ ^{13}C ratios of the graphite were measured using the 0.5 MeV CAIS accelerator mass spectrometer. A comparison was made between the sample ratios and the measured ratio of oxalic acid I (NBS SRM 4990). The $^{13}C/^{12}C$ ratios of the sample were measured separately using a stable isotope ratio mass spectrometer and expressed as $\delta^{13}C$ relative to PDB, with an error of less than 0.1‰.

The values resulting from the analyses were described using the delta notation ($\delta = [(R_{sample}/R_{standard} - 1) \times 1000]$) (Coplen, 1994). To prevent confusion in the presentation of isotopic ratios, the recommendation of the Commission on Atomic Weights and Isotopic Abundances of the International Union of Pure and Applied Chemistry was followed. The reference standards for carbon ($R = {}^{13}C/{}^{12}C$) and oxygen ($R = {}^{18}O/{}^{16}O$) isotopic values are V-v-PDB (*Vienna Pee Dee Belemnite*) and v-SMOW (*Vienna Standard Mean Ocean Water*), respectively (Coplen, 1995).

2.5. Interpretation of $\delta^{13}C$ and $\delta^{18}O$ data

Fixing carbon through the Calvin Cycle, C_3 photosynthetic metabolism plants comprise 85% of the biomass of terrestrial plants, represented by shrubs, trees, and high-latitude, high-elevation, and cold-season grasses (McFadden, 2005). On the other hand, C_4 photosynthetic metabolism plants fix carbon using the Hatch-Slack cycle and correspond to 5-10% of terrestrial plant biomass (grasses and herbaceous plants; Ehleringer and Cerling, 2002). The third and least percentage of terrestrial plants, the CAM (Crassulacean Acid Metabolism) pathway, includes succulents (McFadden, 2005).

Considering the influence of elevation on C_3 plant signatures at altitudes above 3000 meters (Cabido et al., 1997; McFadden, 2005), we disregarded such influence for the study, as the municipality of Paripiranga, Brazil has an elevation of 430 meters, and therefore does not exhibiting high values.

The interpretation of carbon isotopic values ($\delta^{13}C$) found in the teeth and bones of medium to large herbivorous mammals relied on the fractionated values of the consumed plant's photosynthetic pathway (C_3 and C_4; Koch, 2007). For C_3 plants, the values are lower, $\delta^{13}C = -27 \pm 3‰$, for C_4 plants, higher values, $\delta^{13}C = -13 \pm 2‰$, and finally, for CAM plants, values intermediate between C_3 and C_4 (McFadden, 2005; Koch, 2007). Here, we consider the standard enrichment value in herbivores as +14‰ ($\varepsilon^*_{bioapatite\text{-}diet}$; Cerling and Harris, 1999).

Thus, animals that feed on C_3 plants exhibit a value of -13‰, for C_4 plants, a value of 1‰, and among them, a diet of both plants. $\Delta^{13}C$ values < -13‰ indicate an exclusive C_3 plant diet (browser); values > 1‰ indicate an exclusive C_4 plant diet (grazing); and values between -13‰ and 1‰ indicate a mixed diet composed of both C_3 and C_4 plants.

We utilized the Dietary mixing models of Phillips (2012) to measure the proportion of different plants in the animal's diet, where f_1 = C_3 plant ($\delta^{13}C_1$), f_2 = C_4 plant ($\delta^{13}C_2$), and $\delta^{13}C_{mix}$ corresponds to the carbon isotope signatures obtained for the analyzed species. We applied the enriched values of C_3 = -13‰ and C_4 = 1‰. These were used in conjunction with equations (2) and (3) in Excel (Microsoft Corporation, Redmond, Washington):

$$\delta^{13}C_{mix} = \delta^{13}C_1 f_1 + \delta^{13}C_2 f_2 \qquad (2)$$

$$1 = f1 + f2 \qquad (3)$$

To interpret the habitats of the fauna found in the caves of Paripiranga, we considered the enrichment values proposed by Domingo et al. (2012) and replicated by various authors (e.g., Omena et al., 2021; Dantas et al., 2020; 2021). Values between −17‰ and −12‰ represent low-density forest; −12‰ and −7‰, arboreal savannah; −7‰ and −2‰, arboreal to open savannah; and −2‰ to 6‰, open savannah.

The oxygen values in vSMOW were obtained by converting the values in vPDB through equation (4) (Coplen et al., 1983).

$$\Delta^{18}O_{vSMOW} = 1.0392 \text{ x } \delta^{18}O_{vPDB} + 30.92 \qquad (4)$$

When discussing stable oxygen isotopes in mammals, Koch (2007) reports that oxygen composition is reflected by the natural cycles of intake (respiration and ingestion) and output (respiration, transpiration, and excretion) of the organism. Bocherens and Drucker (2013) pointed out that oxygen is primarily absorbed through water intake and food consumption. Oxygen isotope values in plant tissues are, in most cases, similar to those of local precipitation from bodies of water (e.g., ponds, rivers, and lakes), allowing comparison with $\delta^{18}O$ in these mammals (MacFadden et al., 1999; Sponheimer and Lee-Thorp, 2001).

The concentration of $\delta^{18}O$ in fossil mammal tissues also allows inference about temperature and aridity variations. Temperature is the main driving factor in $\delta^{18}O$ value variations in temperate regions, while precipitation amount drives this variation in tropical regions with temperatures above 20°C, exhibiting lower values with increasing precipitation (Dansgaard, 1964), allowing a well-marked seasonal variation of oxygen isotope records in mammal fossil tissues (Silva et al., 2023). Therefore, in tropical regions, higher levels of $\delta^{18}O$ suggest drier periods, while lower levels indicate increased humidity due to high precipitation.

3. Results and Discussion

3.1. Radiocarbon datings AMS

The Paripiranga (Bahia, Brazil) region exhibits a rich diversity of fossil mammals, such as *Coendou* sp., *Mazama gouazoubira*, *Palaeolama major*, *Toxodon platensis*, *Hippidion principale*, *Smilodon populator* (Nascimento et al., 2020), *Eremotherium laurillardi*, *Holmesina* sp., *Catonyx cuvieri* (Nascimento et al., 2024, in press). However, in this study, we only dated four meso-megamammals and a small mammal using ^{14}C AMS.

The results of the radiocarbon dating ^{14}C AMS of bioapatite ($^{14}C_{bioapatite}$) from the taxa that inhabited the region comprise ages between 7200 years and 30,000 years (small mammal 7,272-7,423 cal years BP; *T. platensis* 12,836-12,978 cal years BP; *C. cuvieri*, 14,142-14,536 cal years BP; *Holmesina* sp., 14,999-15,347 cal years BP; *P. major*, 29,891-30,758 cal years BP). However, diagenesis in the carbonate present in bones and enamel is influenced over time, and radiocarbon dating in bioapatite exhibits younger values than those made in collagen (Table 1.) (Zazzo and Saliége, 2011; Zazzo, 2014).

In this way, after applying the regression developed by Dantas and Cherkinsky (2023) for the conversion of $^{14}C_{bioapatite}$ to $^{14}C_{collagen}$, we obtained suggested overall values between ~7600 years and ~36,000 years ($^{14}C_{collagen}$; cal years BP; Table 1), showing a chronological distribution corresponding to the Pleistocene-Holocene. After the conversion, new values with older ages were presented for each species in $^{14}C_{collagen}$: small mammal 7,675-7,845 cal years BP; *T. platensis* 14,320-14,747 cal years BP; *C. cuvieri*, 17,057-17,341 cal years BP; *Holmesina* sp., 17,706-18,159 cal years BP; *P. major*, 35,513-36,379 cal years BP (Table 1; Figure 2).

Table 1. Mammals taxa whose fossils were found in Furna do Cazuza*, Gruta do Bom Pastor**, and Borboletas Cave*** (Paripiranga/BA), carbon isotopic values (δ^{13}C, ‰), proportion (pi, in %) of C_3 and C_4 plants, oxygen isotopic values (δ^{18}O,) and radiocarbon dating converted to collagen ($^{14}C_{collagen}$; 2α rang Cal yr BP – SHCal20). Carbon ($\delta 13C_{vPDB}$) and Oxygen ($\delta 18O_{vPDB\ e\ SMOW}$).

Sample	**14C$_{bioapatite}$**	**14C$_{collagen}$**	**Calibrated Age**	**δ^{13}C ‰**	***pi*C$_3$**	***pi*C$_4$**	**δ^{18}O (‰) vPDB**	**δ^{18}O (‰) vSMOW**	**Taxa**	**Habitat**
UGAMS 63250*	12380 ± 30	14160	17057-17341	-13,12	1	_	-4.39	26,39	*Catonyx cuvieri*	low-density forests
UGAMS 63251*	12770 ± 50	14647	17706-18159	-9,83	0,77	0,23	-4.62	26,16	*Holmesina*	tree savanna
UGAMS 63255*	6460 ± 30	6960	7675-7845	-13,13	1	-	-5.16	25,60	Small mammal	low-density forests
UGAMS 63252**	25940 ± 200	31712	35513-36379	-12,02	0,93	0,07	-2.13	28,72	*Palaeolama major*	arboreal to open savannah
UGAMS 63253***	11030 ± 25	12486	14320-14747	-6,81	0,56	0,44	-2.89	27,94	*Toxodon platensis*	low-density forests

The most recent age of the small mammal analyzed, compared to the other samples, is because the sample was found along with sediment taken from inside the skull of *C. cuvieri*, which may be linked to a secondary depositional event, indicating a difference of approximately 10,000 years.

Few chronological data are presented for *C. cuvieri* in the BIR, in the study area (see Figure 1). Neves and Piló (2003) reported AMS ^{14}C dates on bones of the species found in caves in Lagoa Santa, Minas Gerais, with values calibrated using the SHCal20 curve: 11208-11522 cal yr BP (Gruta Cuvieri), 13290-13515 cal yr BP, and 20607-21076 cal yr BP (Lapa dos Tatus). In the studies by Hubbe et al. (2013), in the Abismo Iguatemi cave in the state of São Paulo, ages of 10,800 ± 60 (uncalibrated) were reported, and after calibration, 12612-12858 cal yr BP.

In the Gruta da Marota cave, located in the central region of Bahia, Dantas et al. (2021) presented radiocarbon ^{14}C bioapatite dates for the species ranging from 11,152 to 11,019 cal yr BP, converted to ^{14}C collagen = 14,839-15,165 cal yr BP (using the SHCal20 curve; Dantas and Cherkinsky, 2023). The chronological data of *C. cuvieri* found in Paripiranga, Bahia, correspond to the same period of species distribution in the region, the Late Pleistocene.

The occurrence and chronostratigraphic distribution of *Toxodon platensis* are well-documented for the Pleistocene period in South America between 50 kyrs and 35 kyrs (Miño-Boilini et al., 2006) and in various regions of Brazil, more precisely in the RIB, often associated with *Eremotherium laurillardi* and *Notiomastodon platensis* (Dantas et al., 2013a; 2013b). Dantas et al. (2013a) present this record by conducting a brief chronological survey of these three species, indicating *E. laurillardi* dates between ~15 kyr and 30 kyr; *N. platensis*, ~10 yrs and 60 kyrs; and *T. platensis*, ~10 kyr and 50 kyr.

The dating of the *Toxodon* specimen found in Paripiranga falls within the expected range for the species, with values close to those reported by Cherkinsky, Dantas, and Cozzuol (2013), who reported ages between 10,050 ± 30 and 11,310 ± 30 years BP (converted and calibrated to 13,091-13,242 and 15,106-15,485 cal kyr BP, respectively, using the SHCal20 curve)

The age assigned to *Holmesina* sp. In Paripiranga is consistent with the relative dating of *Holmesina*, *Pampatherium*, and *Tonnicinctus* further south on the continent (Góis et al., 2012; 2015). Moura de Jesus (2019) presents a dating conducted using bioapatite, with a value of 20,970 ± 40, converted to collagen and recalibrated to 29,148-29,649 cal kyr BP (SHCal20 curve).

Among the results of AMS 14C dating obtained for Paripiranga, Bahia, that of *Palaeolama major* displays the oldest value (35,513-36,379 cal years BP). This age corresponds to the range found in other studies and different methods. Dantas (2011), through Electron Spin Resonance (ESR) dating, found an age of 38 kyr BP for the species studied in Poço Redondo, Sergipe.

In Iraquara, BA, values for *Palaeolama major* were obtained as follows: $^{14}C_{bioapatite}$ = 20,850 ± 50; $^{14}C_{collagen}$ = 24,993 ± 50 4143; and calibrated to 29,077–29,248 years BP (Dantas et al., 2017; Dantas and Cherkinsky, 2023). In the Caverna do Ioiô, Bahia, Etlink et al. (2020) obtained, through bioapatite, 20,850 (±50), converted to collagen and calibrated on the SHCal20 curve, 29004-29272 cal years BP. The connection between the intervals presented in this article and those found in the literature is evident.

3.2. Isotopic paleoecology (δ^{13}C, δ^{18}O) e Paleoenvironmental Reconstruction

The different taxa analyzed that lived during the Pleistocene-Holocene in the region of Paripiranga, northeastern Bahia (*C. cuvieri*, *Holmesina* sp., *P. major*, *T. platensis*, small mammal), exhibit isotopic values indicating a mostly mixed diet, with δ^{13}C values ranging from -13.13‰ to -6.81‰ (Table 1; Figure 2).

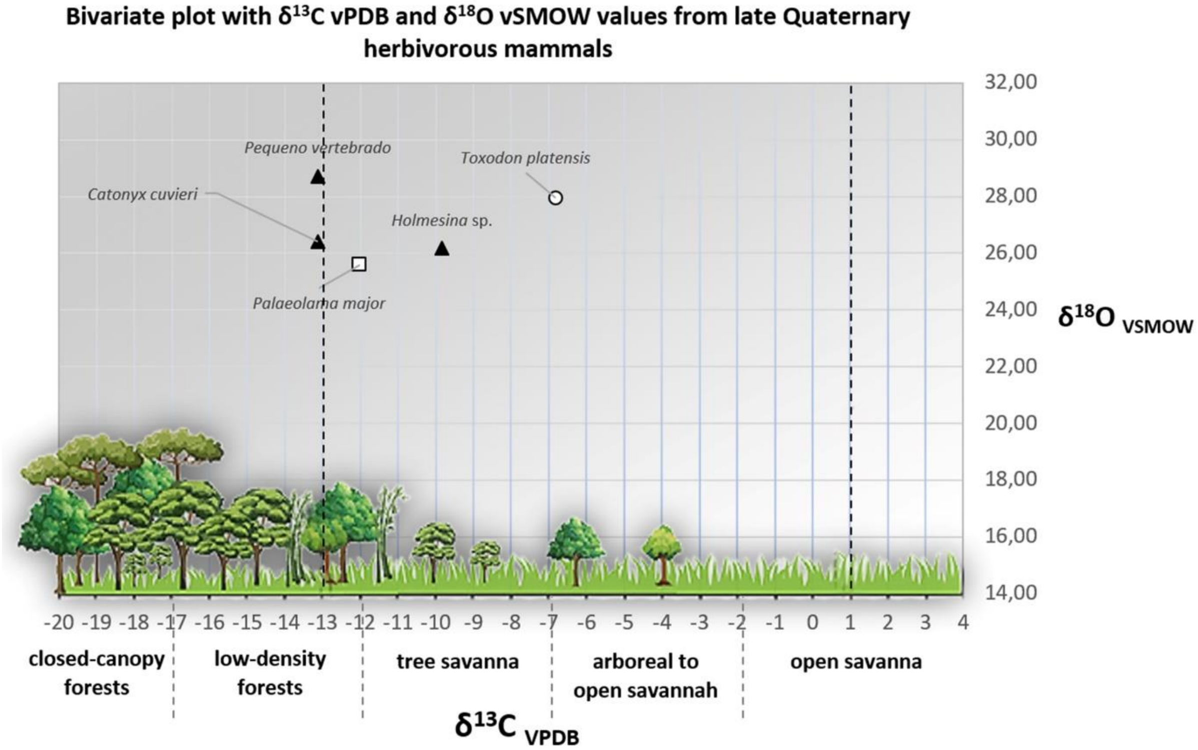

Figure 2. Bivariate plot with $\delta^{13}C_{VPDB}$ and $\delta^{18}O_{vSMOW}$ values from late Quaternary herbivorous mammals of the Northeastern Bahia. The enrichment ranges of $\delta^{13}C$ values were according Cerling and Harris, 1999 ($\mathcal{E}^* = 14‰$). The traces represent the average of $\delta^{13}C$ values for C_3 and C_4 resources.

For the region, the analyzed individual of *C. cuvieri* presented a $\delta^{13}C$ value of -13.12‰ (p_iC3 = 100%), thus having an exclusively C_3 plant diet, being a browser. In another study, Dantas et al., (2021), analyzing another individual of *C. cuvieri* in Gruta da Marota, Andaraí/BA, found different values, indicating a mixed diet with 80% consumption of C_3 plants (p_iC3 = 80%) and 20% C_4 plants. This variation may be linked to different strategies to avoid competition with other animals in the environment. The $\delta^{13}C$ value of -13.1‰ found fits into a low-density forest habitat described by Domingo (2012).

We emphasize the importance and correlation of the faunas studied here with the work of Dantas et al., (2020), which provides data on various animals that lived in the Intertropical Brazilian Region (RIB) during the Pleistocene, especially *Smilodon populator*, *H. paulacoutoi*, *C. cuvieri*, *P. major*, *E. laurillardi*, *T. platensis*, which also have occurrences in Paripiranga (Nascimento et al., 2020; current study). Dantas et al., (2020) infer for an individual of *C. cuvieri* (Sergipe) a diet based on C_4 grass plants (p_iC_4 = 67%), with a $\delta^{13}C$ value of -3.4‰, corresponding to a tree to open savannah environment, which may indicate once again a possible dietary adjustment to avoid direct competition for resources.

Our data show for *Holmesina* sp. A δ^{13}C value of -9.83‰ (p_iC$_3$ = 77%), indicating a mixed diet with a preference for C$_3$ plants, suggesting it could inhabit a wooded savannah environment. The same species is reported with other δ^{13}C values, such as -5.7‰, with a preference of 59% for C$_4$ plants as browsers in Caetanos/BA (Lessa et al., 2021), δ^{13}C = -6.8‰ in Anagé/BA (Silva et al., 2019), and δ^{13}C = -6‰ in Sergipe (Dantas et al., 2020), all indicating a mixed diet with a preference of 56% for C$_3$ grass plants.

The results presented extend the range proposed by Lessa et al., (2021) from -6.8% to 5.7% to -9.83 to -5.7%, demonstrating the variation in the mixed diet with a possibility of a higher percentage of C$_3$ plant consumption. This suggests that the species could inhabit a transitional habitat between a wooded savannah and open savannah. For a better comparison with our results, the values from the studies were recalculated with an enrichment of +14, following Cerling and Harris (1999).

The isotopic analysis of *P. major* showed a δ_{13}C value of -12.02‰ (p_iC$_3$ = 93%), indicating a mixed diet with a preference of 93% for C$_3$ plants and 7% for C$_4$ plants. This suggests that the species inhabited a low-density forest environment like *C. cuvieri* found in the region. The values found in Sergipe by Dantas et al., (2020), show δ^{13}C = -7.3‰, with a diet of 59% corresponding to C$_3$ plants (p_iC$_3$ = 59%; recalculated using +14 enrichment), indicating a habitat of wooded savannah (Domingo, 2012). On the other hand, values found in specimens in the central region of Bahia (Toca dos Ossos, Ourolândia/BA) by Pansani et al., (2019) are δ^{13}C = -5.0‰ with a preference for 57% C$_4$ plants. Thus, we understand that this species may show a range from -5.07‰ to -12.02‰, covering habitats from low-density forests to wooded savannah to open savannah (Figure 2).

The species *Toxodon platensis* is certainly among the most representative animals within the megafauna, along with *E. laurillardi* and *Notiomastodon platensis* (Cartelle, 1992;1999; França et al., 2015). Our study resulted in δ^{13}C values of -6.81‰, indicating a mixed diet with a preference for 56% C$_3$ plants, suggesting an environment ranging from wooded to open savannah. Other values are found across the BIR for the species. McFadden et al., (1999) show two δ^{13}C values for the Ourolândia/BA region (Toca dos Ossos), -12.6‰ and -7.7‰, both with a preference for C$_3$ plants. For the municipality of Caetanos/BA, Lessa et al. (2020; central region of Bahia) presents results of a diet consisting of 100% C$_4$ plants, indicating a specialist herbivore browser.

Various ranges for *T. platensis* $\delta^{13}C$ values are inferred, with Dantas et al., (2020) proposing a range of -9.8‰ to -3.3‰, Omena et al., (2021) suggesting a range of -12.3‰ to 0.0‰, and Lessa et al., (2021) proposing -12.3 to 1.3‰. Our results fall within the range proposed by Lessa et al., (2021) of -12.3‰ to 1.3‰. Overall, our data suggests a transitional habitat between low-density forests and transitional zones from wooded to open savannah (Figure 2).

Considering that higher levels of $\delta^{18}O$ suggest drier periods, while lower levels indicate increased humidity due to high precipitation, the results do not show abrupt changes in climate (Figure 2) when compared to the results presented by Omena et al. (2021). They indicate a drier climate like that proposed by them.

4. Final Remarks

The new chronological data obtained by AMS ^{14}C for the species *Catonyx cuvieri*, *Holmesina* sp., *Palaeolama major*, *Toxodon platensis*, and a small mammal allow us to conclude that the fauna inhabiting the region of Paripiranga, Bahia, Brazil is correlated with other animals that lived during the Late Pleistocene (36.6 to 7.6 kyr cal BP). The isotopic diet and the percentage preferences between C_3 and C_4 plants for the taxa studied here suggest that these taxa lived in a transitional habitat between low-density forests and transitional zones from tree savannah to open savannah ($\delta^{13}C$ = -13,1‰ a 6,8‰).

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4.3 ARTIGO 3 – THE PALEONTOLOGICAL AND SPELEOLOGICAL WEALTH OF THE MUNICIPALITY OF PARIPIRANGA, BAHIA, BRAZIL: POTENTIAL FOR HERITAGE EDUCATION AND THE ESTABLISHMENT OF MEMORY SPACES

A riqueza Paleontológica e Espélica do Município de Paripiranga, Bahia, Brasil: Potencial para a Educação Patrimonial e Criação de Espaços de Memória

Seguindo as normas da revista

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Abstract

In the region of Paripiranga, Bahia, in the northeast of Brazil, there is a project that envisions the establishment of a cement factory, which foresees direct damage to the speleological and paleontological heritage, which must be protected according to the current federal legislation of Brazil. There have been initiatives for heritage education by non-governmental organizations and research groups from the Federal University of Alagoas. However, this speleological and paleontological heritage is still little known, making its disclosure and protection urgent. In light of this, this paper presents the speleological richness and fossil diversity of the underground cavities of Paripiranga, showcasing the potential for heritage and environmental education, as well as the creation of memory spaces aimed at preserving fossils and cavities as cultural heritage. Through decades of field studies by the laboratory team, including the creation of maps and visits to natural cavities, it has been possible to document that Paripiranga and the surrounding region are highly relevant on the national tourist/scientific scene, containing at least six karst deposits with the occurrence of rich past biodiversity, especially Pleistocene fossil vertebrates documented since the 1980s. Additionally, other deposits have been documented, highlighting their richness and diversity of speleothems and cave fauna, biodiversity, among other attributes. Based on this information and drawing on the previous experience of municipalities like Maravilha, Alagoas, the proposal to create memory spaces, such as museums and cultural centers, aims to promote the connection of the population with its history and heritage. These data are essential for the development of preservation plans and decision-making related to the protection of natural cavities. These actions can also drive local and regional socio-economic development while contributing to the preservation of the environment and the memory and culture of the region.

Keywords: geoheritage; paleontology; culture

Resumo

Na região de Paripiranga, Bahia, nordeste do Brasil, há um projeto que prevê a implantação de uma fábrica de cimento, o qual prevê danos diretos ao patrimônio espélico e paleontológico, que devem ser protegidos de acordo com a legislação federal vigente do Brasil. Houve iniciativas de ações de educação patrimonial por Organizações não-governamentais e de grupos de pesquisa da Universidade Federal de Alagoas. Entretanto, esse patrimônio espélico e paleontológico ainda é pouco conhecido, tornando urgente a sua divulgação e proteção. Diante disso, esse trabalho apresenta a riqueza espeleológica e diversidade fossilífera das cavidades subterrâneas de Paripiranga, mostrando o potencial para educação patrimonial e ambiental e criação de espaços de memória visando a preservação de fósseis e cavidades como patrimônio Cultural. Através de décadas de estudos de campo da equipe do laboratório, elaboração de mapas e visita as cavidades naturais, pôde-se documentar que Paripiranga e região têm grande relevância no cenário turístico/científico nacional, contendo pelo menos seis depósitos cársticos com ocorrência de uma rica biodiversidade pretérita, especialmente de vertebrados fósseis do Pleistoceno, documentados desde a década de 1980. Além disso, outros depósitos foram documentados, destacando sua riqueza e diversidades de espeleotemas e espeleofauna, biodiversidade dentre outros atributos. Partindo dessas informações e com base na experiência prévia de municípios como Maravilha, Alagoas, a proposta de criar espaços de memória, como museus e casas de cultura, visa promover a conexão da população com sua história e patrimônio. Esses dados são fundamentais para a elaboração de planos de preservação e tomadas de decisões relacionadas à proteção de cavidades naturais. Essas ações podem ainda, impulsionar o desenvolvimento socioeconômico local e regional, ao mesmo tempo em que contribuem para a preservação do ambiente e da memória e cultura da região.

Palavras-chave: patrimônio; paleontologia; cultura

1. Introduction

Among the various types of Quaternary sedimentary deposits found in nature, cave systems are indeed among the richest in terms of fossil preservation and occurrence, especially of vertebrates (Simms, 1994; Vasconcelos et al., 2015; Vasconcelos et al., 2018; Medeiros, 2018; Nascimento et al., 2020). In Brazil, in the Brazilian Intertropical Region (RIB) (Cartelle 1999; Oliveira et al., 2017), in the northeast of Brazil, the state of Bahia has a diversity of karst deposits. The municipality of Paripiranga, Bahia, is located in the RIB and has natural cavities as its main sedimentary deposits, rich in Pleistocene paleontological material (Dantas, 2005; Dantas et al., 2008; Donato et al., 2010; Silva et al., 2012; Lima, 2017, Nascimento, et al. 2022). Both natural cavities and fossils are important Brazilian cultural assets and must be protected (Brazil, 1942; 1988; 2007).

In this context, there is a project for the establishment of a cement factory in the Paripiranga region, with a forecast of extracting three million tons of limestone per year, using an open-pit mining method that predicts direct or indirect impacts on at least 84 natural cavities and fossils in the region (Cimar, 2014). Among these impacts, a direct impact on seven natural cavities is foreseen, which could be destroyed due to the factory implementation, with mitigating measures already planned according to the Ministry of Environment legislation (Cimar, 2014).

Therefore, the disclosure of these cavities focused on the richness of biodiversity and the presence of fossils, as well as their preservation through heritage education and memory spaces or museums, is urgent in the Paripiranga region. The first activities carried out to disseminate knowledge about natural cavities (e.g. caves, abysses, grottos, pits) to the population were conducted by the Non-Governmental Organization (NGO), Grupo Mundo Subterrâneo de Espeleologia (GMSE), which seeks to arouse interest in the protection of these assets through lectures in schools and visits to some of these cavities in the region (Silva et al., 2020). In addition, in recent decades, the team of researchers and students from the Integrated Laboratories of Paleontology and Speleology of the Natural History Museum of the Federal University of Alagoas has intensified educational activities in the region.

An alternative is the creation of a memory space, such as museums and cultural centers, which boost and accelerate the education of the region as a whole, in addition to providing significant socio-economic contributions through local and regional tourism. This has been observed in some cities in Alagoas, which have undergone significant socio-economic and socio-environmental changes after the implementation of a museum in Maravilha and cultural centers in Inhapi and Olho D'Água do Casado (Silva, 2008).

Memory spaces are intentional memorials that guarantee the identity of a certain space or place (Nora, 1984), where information needs to be preserved, such as museums, archives, or collections that are records of another "era" (Nora, 1993). The creation of memory spaces that seek to centralize regional knowledge, such as museums and cultural centers, are significant steps when the focus is on connecting the population with its past and present. Topics that involve regional geographical history – political and human geography, geomorphology, geology – biological history, human interaction in the region – archaeology, paleontology, ethnobiology, botany, climates, and biome – have always attracted the interest of everyone through educational activities, and the more the population has access to information, the more involved they will be in preserving their memory. This corresponds to what Chagas (1990, p.90) stated: "The testimonies of culture and the environment are of interest to museology as supports of information, as representations of memory, and this justifies their preservation, research, and exhibition."

Therefore, this study aims to present the speleological richness and fossil diversity of underground cavities in the municipality of Paripiranga, to demonstrate the potential for heritage and environmental education, as well as the creation of memory spaces aimed at preserving fossils and cavities as cultural heritage.

The creation of memory spaces for preservation and scientific dissemination in this region of Bahia, including information about fossils and caves, would be possible due to the following factors:

1) Natural cavities (e.g. caves, grottos, pits, abysses, burrows) present in the state of Bahia play an important role in the national tourist/scientific scene. As they constitute a natural and cultural heritage of immense value, cavities are declared federal assets by the Federal Constitution, art. 20, X, with the duty to care for them, determining concrete measures for their conservation.
2) Subterranean cavities provide fossil preservation and store a wealth of past biodiversity in a unique way.
3) Fossils, besides being protected by laws (Law 4,146 of March 4, 1942), have scientific and didactic value, constituting objects of social and cultural interest.

4) There are no museums or memory spaces in the Paripiranga region and its surroundings, and there is a lack of information, integration, and promotion of the relationship between society and its heritage.
5) Permanent dissemination of Speleology and Paleontology, as well as the presence of fossils in the municipality, can generate significant improvements in the socio-economy, creating more income opportunities for the population.
6) There is an extensive paleontological collection in the state of Bahia.

These aspects will be discussed in the following sections: a) speleological and paleontological heritage of the region; b) potential for heritage, environmental education, and memory spaces.

2. Geological Context of the Study

In the Brazilian territory, there are several regions composed of terrains conducive to the formation of natural cavities, as well as complex underground water systems; these environments are also referred to as karstic environments. The karstic relief in these regions presents morphology that can be subdivided into exokarst and endokarst, with characteristic features such as sinkholes, ponds, residual features, uvalas, lapiaz, blind valleys, springs, and sinks, as well as speleothems, among others (Piló, 2000; Piló and Auler, 2019). These regions can provide valuable Speleological Heritage, confirming that the territory of Bahia is rich and varied when it comes to karst and caves (Jansen et al., 2012; Pereira et al., 2022).

Karmann and Sanchez (1979) proposed the Province-District-System model, relating the existing carbonate areas in the country, emphasizing the most important from a speleological perspective. Among the known Carbonate Provinces in the state of Bahia are the Una Group, Caatinga Formation, and Caboclo Formation – located in the Chapada Diamantina, the Bambuí Group located in Western Bahia, the Canudos Supergroup in the north/northeast region, and to the south is the Rio Pardo Group; the study area is located in the Canudos Supergroup (Figure 1).

Figure 1. Map of Karst Regions in the state of Bahia, Brazil. Red rectangle indicating the study area – municipality of Paripiranga, Bahia.

The municipality of Paripiranga is located in the northeast of the state of Bahia, bordering to the north with Coronel João de Sá, to the west with Adustina, and to the east and south with the municipality of Simão Dias - Sergipe, being part of the hydrographic basin of the Vaza Barris River. The municipal seat is at an altitude of 430 meters (Vieira et al., 2005) (Figure 2). According to data from the National Cave Registry (CNC, 2022), there are 81 cavities, while data provided by the National Speleological Information Registry - CANIE (CECAV/ICMBIO, 2022) records 82 cavities. According to the Mundo Subterrâneo de Espeleologia Group - GMSE, a local group, more than 120 cavities have already been visited.

According to Pereira et al. (2017), the carbonate rocks where the cavities in the municipality of Paripiranga are located are part of the Olhos D'água Formation (Figure 3). Neoproterozoic rocks of the Sergipana Folding Belt, consisting of metasedimentary limestones: metacalcarenite and metadolomite, metarhythmites, metapelites, and metacherts, make up the Olhos D'água Formation (Silva Filho et al., 1977).

Figure 2. Map showing the location of Natural Cavities in Paripiranga, BA.

Figure 3. Geological Map of the northeastern region of Bahia, with a focus on the municipality of Paripiranga – composed of Neoproterozoic rocks from the Sergipana Folding Belt.

3. Methodology and Data

The team of researchers and students from the Integrated Laboratories of Paleontology and Speleology at the Natural History Museum of the Federal University of Alagoas has been conducting activities in the Bahia region for over 20 years. The research has intensified in the last 10 years, particularly in the karstic region of the municipality of Paripiranga, Bahia. The field information was collected over the years from 2012 to 2023, with an emphasis on the period from 2016 to the present, providing new data for the compilation of the information used here.

The campaigns carried out in the Karstic region required logistics and methodologies different from those used in other types of surface deposits (Mendes, 1965, 1982; Nobre and Carvalho, 2010). Due to being natural underground cavities, safety is one of the main concerns.

The major challenges in these activities are related to the physical aspect, whether it be the aphotic zone (without light) or the development of the cavity.

With that in mind, many natural cavities require knowledge of vertical techniques for their exploration. Depending on the size and duration of the activity, other techniques such as the assembly of structures like bridges, scaffolding, and fixed pulley systems are used to ensure a safer execution of this activity (Figures 4 and 5).

Figure 4. Photograph of vertical techniques being applied for entrance into the abyss of the Furna do Cazuza cave – photograph: Daniel Menin, 2019.

Figure 5. Structure assembled for conducting research activities inside the Furna do Cazuza cave – photograph: Johnson S. O. Nascimento, 2020.

The collection of paleontological materials from the natural cavities found in Paripiranga was carried out with the aid of tools such as geological hammers, pickaxes, shovels, chisels, brushes, and trowels. All materials underwent the process of packaging, protection, and received labels with identification for transportation to the laboratory for treatment, study, and cataloging in the Paleovertebrates collection of the Laboratórios Integrados de Paleontologia e Espeleologia of the (LIPE-SP-MHN-UFAL Integrated Laboratories of Paleontology and Speleology, within the Paleontology Sector of the Museu de História Natural of the Universidade Federal de Alagoas (LIPE-SP-MHN-UFAL) (Figure 6).

Figure 6. Record of practical collection procedures – protection, packaging, application of label for transportation (Photo: Maria Souza, 2020).

For the creation of the maps in this work, the open-source software QGIS version 3.22.16 was used, following the standards and recommendations by configuring the reference coordinate system (SRC) indicated for the Brazilian territory, SIRGAS 2000, either in metric units using zone 24S in the Universal Transverse Mercator (UTM), or in degrees using geographic coordinates. Spatial databases from official institutions such as the Brazilian Institute of Geography and Statistics (IBGE), the National Speleological Information Registry (CANIE), and 2022 satellite images from Copernicus were used for the development of the digital elevation model.

For the description of the speleological and paleontological heritage, the team classified the natural cavities and their potentials. Efforts were made to engage with residents to understand how the local community perceived and treated the caves and whether there was any knowledge of fossil occurrences or commonly known "*dinosaur bones*" in the region. Subsequently, to assess the potential for memory spaces such as museums and cultural houses, the team built upon previous education activities and initiatives such as the construction of museums in cities with fossil finds.

4. Results and Discussion

4.1. Speleological and Paleontological Heritage of the Region

As a result of speleological and paleontological activities conducted over the past 10 years in the karstic region of the municipality, exokarstic features were observed, including depressions and drainage patterns in the terrain, lapiaz, sinkholes, abysses, as well as endokarstic features, such as the richness and diversity of speleothems and speleofauna, in the realm of speleology. Regarding paleontological aspects, fossil occurrences, diversity, paleoecological inferences, and paleoenvironmental observations were made (Tables 1 and 2).

Table 1. Some characteristics of the cavities visited in the region of Paripiranga, BA.

Table 2. Fossil occurrences in the cavities of the Paripiranga region, BA

The LIPE team met with residents who reported that fossils were removed from the cave, also known as Abismo do Cazuza, in the 1980s and taken to an institution, but there is no final record of these bones (Figure 7).

In the studied region, there are at least seven cavities with fossil occurrences (Figure 8), where, in just one of them, Borboletas Cave, six species of fauna that lived during the late Pleistocene to early Holocene are recognized (Table 2). The wealth of paleontological data, coupled with the numerous caves and abysses in the region (Santana et al., 2010, 2013), provides a rich and important foundation for the implementation of the dissemination and exhibition of both material and immaterial heritage, thereby highlighting the locality in the paleontological and speleological scenario at the regional and national levels.

Figure 7. Images of Pleistocene megafauna vertebrate fossils, extracted from the Furna do Cazuza cave in the 1980s. (Photographs: provided by GMSE).

Figure 8. Distribution of Megafauna occurrences in the municipality of Paripiranga.

Recently, during the 2020 campaign in Furna do Cazuza, the presence of paleovertebrate fossils and remains of the giant sloth skeleton, as reported by Nascimento et al., (in press), was confirmed (Figure 9). It was observed that some of the studied bones are complements to the skeleton of the giant sloth species *Eremotherium laurillardi.*

Figure 9. LIPE team alongside fossils of the giant sloth found inside Furna do Cazuza.

4.2. Potential for heritage education, environmental education, and memory spaces

The data provide important and crucial information, fostering the development of projects focused on heritage and environmental education and the creation of memory spaces. In this sense, Abaide (2010) points out that, rightfully, society should have access to information about the richness of its heritage, including paleontological and speleological aspects (Abaide, 2010). Access to this information, through scientific collections, enables the development of plans and decision-making directly related to the preservation of natural cavities, as well as the historical, landscape, artistic, archaeological, paleontological, ecological, and geoscientific wealth (Pinto, 2009).

After analyses and visits, we emphasize here that the cavities Furna do Fim do Morro do Parafuso, Cavernas do Urutau, Encanto, Descanso, Zumbi, and Gruta do Bom Pastor have the potential for visitation and the creation of memory spaces, with some of them being frequented and already used for environmental education projects. According to Dantas et al. (2009), Gruta do Bom Pastor stands out historically in the region due to tourist visits and cave excursions organized by religious representatives, altering the original features of the cave entrance with the construction of a staircase for the entry of the faithful and the celebration of masses.

The team also observed that other cavities, such as Furna do Fim do Morro do Parafuso (known by some as Caverna dos Caramujos), showed a visible degree of impact due to the entrance of residents who left litter, graffiti on the walls, and broke some speleothems. Another problem is the disposal of domestic, agricultural, and medical waste, as well as animal carcasses inside the underground cavities, directly impacting the cave ecosystem and aquifers (Donato and Ribeiro, 2011; Lino, 2001). Over the years, with the mainly local action of GMSE - a group active in the region, movements were initiated to raise awareness among the population about speleological preservation. Additionally, the potential construction of the cement factory will cause direct damage to these cavities and fossils, necessitating urgent measures for awareness and preservation of these important cultural heritage sites.

A population with socio-environmental awareness can reduce the negative impact on the environment and ecosystems. Based on this, we can project that this change in the Paripiranga region will lead to a decrease, and perhaps even elimination, of these cases of environmental impact. These reports make an important point for the creation of projects in spaces of memory aimed at strategies regarding the importance and awareness of the population regarding heritage and environmental education, demonstrating in practice a socio-economic and socio-environmental return for the region. The initiative to establish a foundation for a living heritage and environmental education project has the potential to educate the local community and influence the region socioeconomically, based on scientific dissemination, the construction of an environment for exchanges and learning between mediators and the population.

In this context, the team from the Museum of Natural History at UFAL (LIPE-SP-MHN-UFAL) has experience with successful local memory projects, such as the Paleontology Museum Otaviano Florentino Ritir in the city of Maravilha and the Casa de Cultura in Inhapi, both municipalities in Alagoas (Figure 10). The city of Maravilha had part of its infrastructure adapted to the project, with sculptures of megafauna animals, trash cans shaped like these animals distributed throughout the city, health products such as soap in the shape of megafauna, among other events related to the theme. This changed the perception of fossils, emphasizing not only their heritage importance but also the use of the image as an influence on tourism and economic attraction in the region.

Figure 10. Facade of the Otaviano Florentino Ritir Paleontology Museum (left) and the Casa de Cultura de Inhapi (right). Photographs: Marcio Adriano Alves, 2023 (Maravilha, AL); Roberto Oscar, 2020.

Similarly, building upon the educational initiatives that have been implemented for decades by the paleontology team at UFAL, the creation of memory spaces in the Paripiranga region aims at preserving this collection and fostering local community engagement with its history. Additionally, these memory spaces, such as museums or cultural centers, can generate socio-economic alternatives for the local population. This will require technical training in paleontological and speleological knowledge specific to the region, with the goal of having individuals who can serve as guides, engage in curatorial activities, welcome visitors (Barreto et al., 2016), among other planned tasks.

Finally, the proposal for the memory space could follow several steps:

i) Direct communication with the community, integrating the socio-political with the socio-environmental aspects through training lectures for both sectors, aiming to educate everyone about the role and importance of preserving the material and immaterial heritage of the region;

ii) Structuring two visitation environments: one in the urban area, in a historic building in the city, consisting of exhibition rooms determined by areas (e.g., Paleontology, Speleology, History, Anthropology, Archaeology, and Biodiversity of the region), as well as rooms for workshops and an advanced research laboratory for the training of students and teachers at different levels of education.

iii) At another time, an advanced visitation point would be created, located in the village of Roça Nova, near the cavity of Gruta do Bom Pastor. This point is considered to have potential due to the strong connection that the local community has with the cave, as reported earlier.

After the elaboration of a management plan, it would be possible to carry out controlled visitations, aiming for eco-sustainable development with low impact, similar to what occurs in various locations in Brazil with large concentrations of natural caves (e.g., PETAR, Vale do Ribeira, Chapada Diamantina, and the caves found in Minas Gerais; Lobo et al., 2008; Santos and Santana, 2023).

Through these initiatives of heritage and environmental education facilitated by these memory spaces, there is also an expectation to raise awareness among leaders in the construction sector, as exemplified by the cement factory construction project. This awareness emphasizes that speleological and paleontological heritage should be preserved for legal reasons and contributes to the socio-economic development and tourism of the region. It requires a collective effort, not only from researchers but from society as a whole.

5. Conclusion

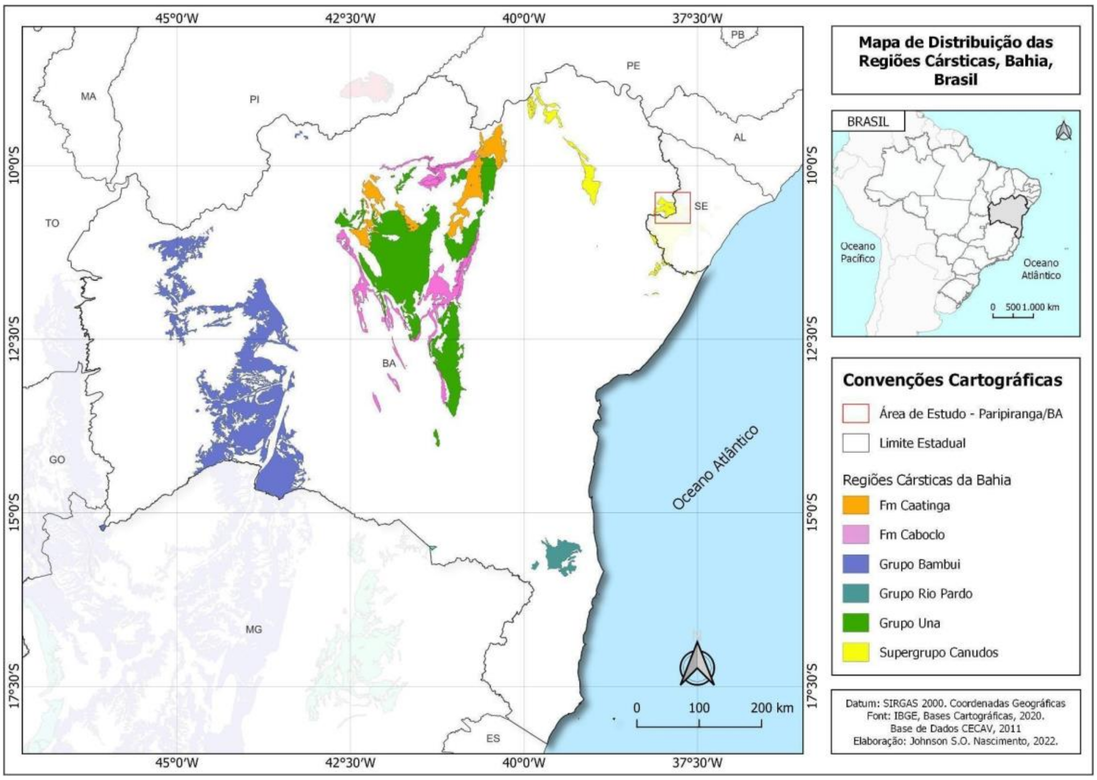
The importance of valuing and promoting the cultural and scientific richness present in the region is evident. Through the conservation, research, and dissemination of these heritages, various benefits can be achieved, not only for researchers but especially for the local community and visitors. Decades of research confirm that the natural cavities in the region are highly relevant in the national tourism/scientific scenario, containing sedimentary deposits that preserve a rich prehistoric biodiversity, especially Pleistocene fossil vertebrates. The existence of potential paleontological sites and the significance of cultural and natural heritage highlight the need for heritage and environmental education for the local population.

The proposal to create memory spaces, such as museums and cultural centers, following the examples of cities like Maravilha, AL, aims to promote the connection of the population with its history and heritage, enabling the preservation and dissemination of scientific knowledge in the region. The formation of an environmentally conscious population would reduce the negative impact on the region's environment and ecosystems, contributing to the sustainability of natural and cultural heritage and stimulating curiosity and learning about the geological and biological history of the municipality.

In this context, it is also emphasized that through actions, a reduction in current environmental impacts in the region's caves and in a future cement extraction project is anticipated. The research identified several caves with fossil occurrences, providing a rich foundation for the implementation of scientific outreach projects, which could drive local and regional socio-economic development through tourism and community involvement with their heritage.

Finally, this paper highlights the relevance of a strategic planning collaboration between the scientific community and municipal and federal spheres, being continuous and open to adaptations, considering the dynamics of both the community and the sciences. By following a process of constant monitoring and evaluation, it will be possible to adjust the strategies for the dissemination of the paleontological and speleological heritage of Paripiranga, Bahia, always aiming for excellence in the conservation, valorization, and diffusion of these treasures from the past, located in the heart of Brazil.

Figures e tables:



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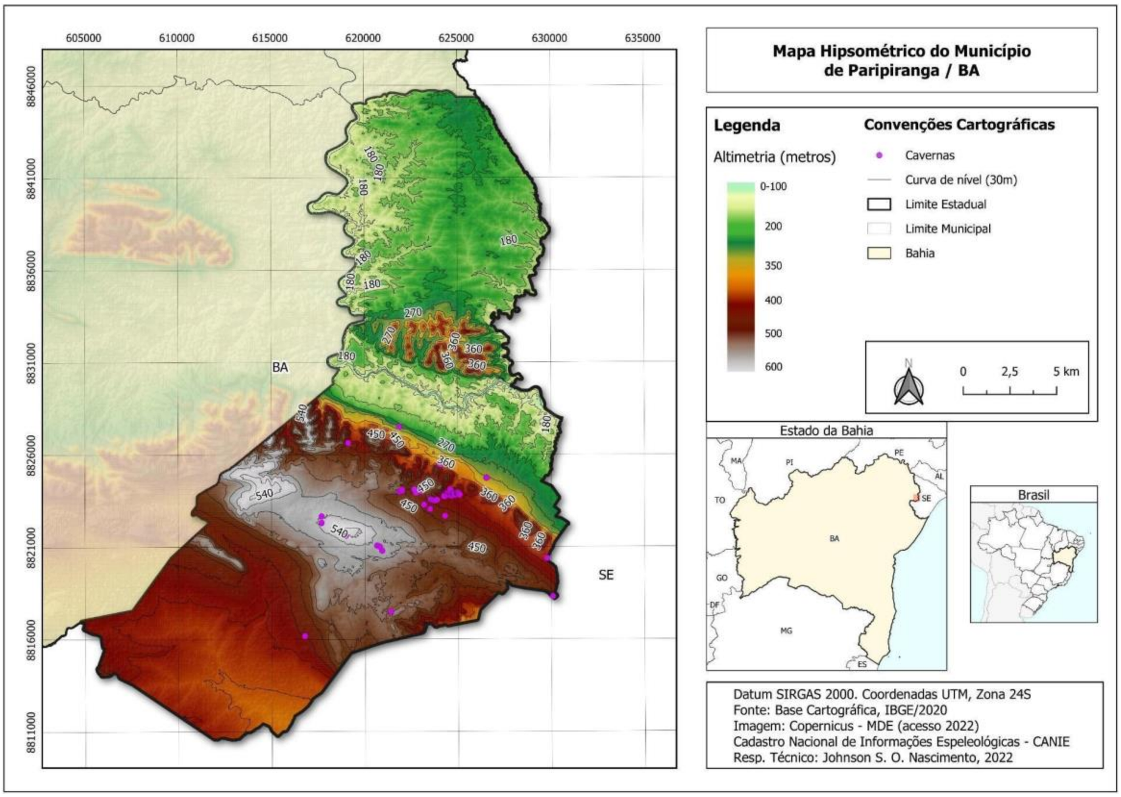

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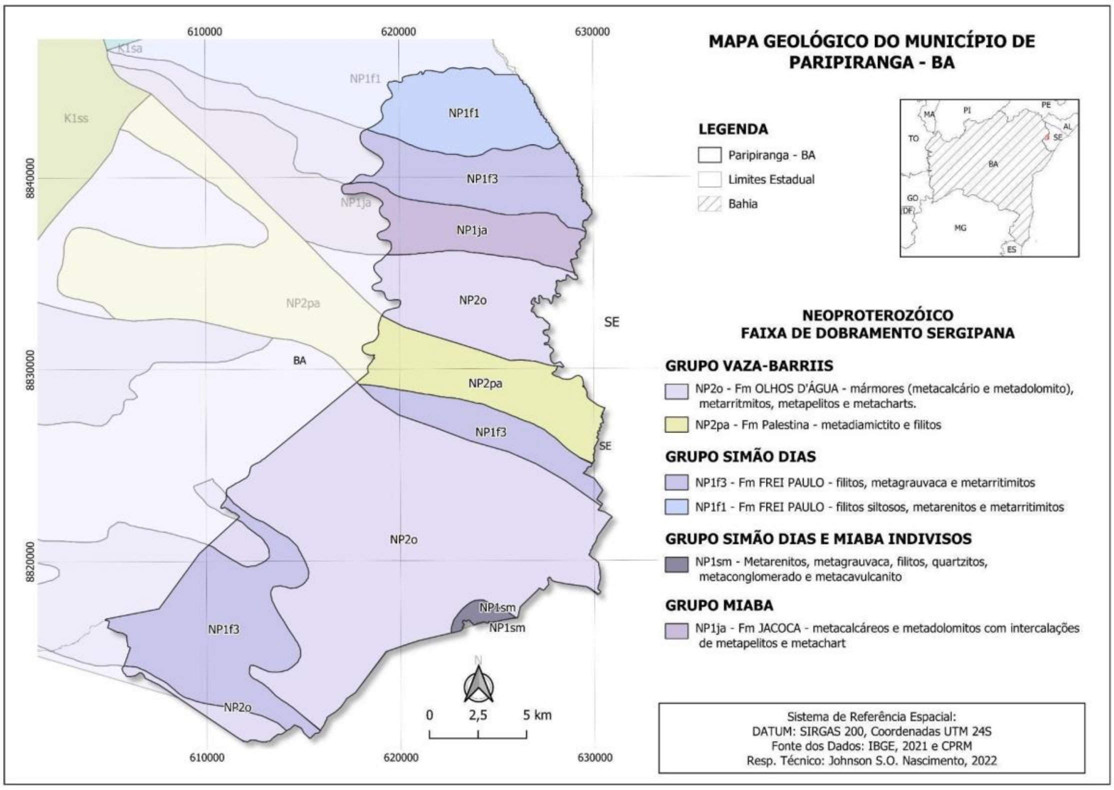

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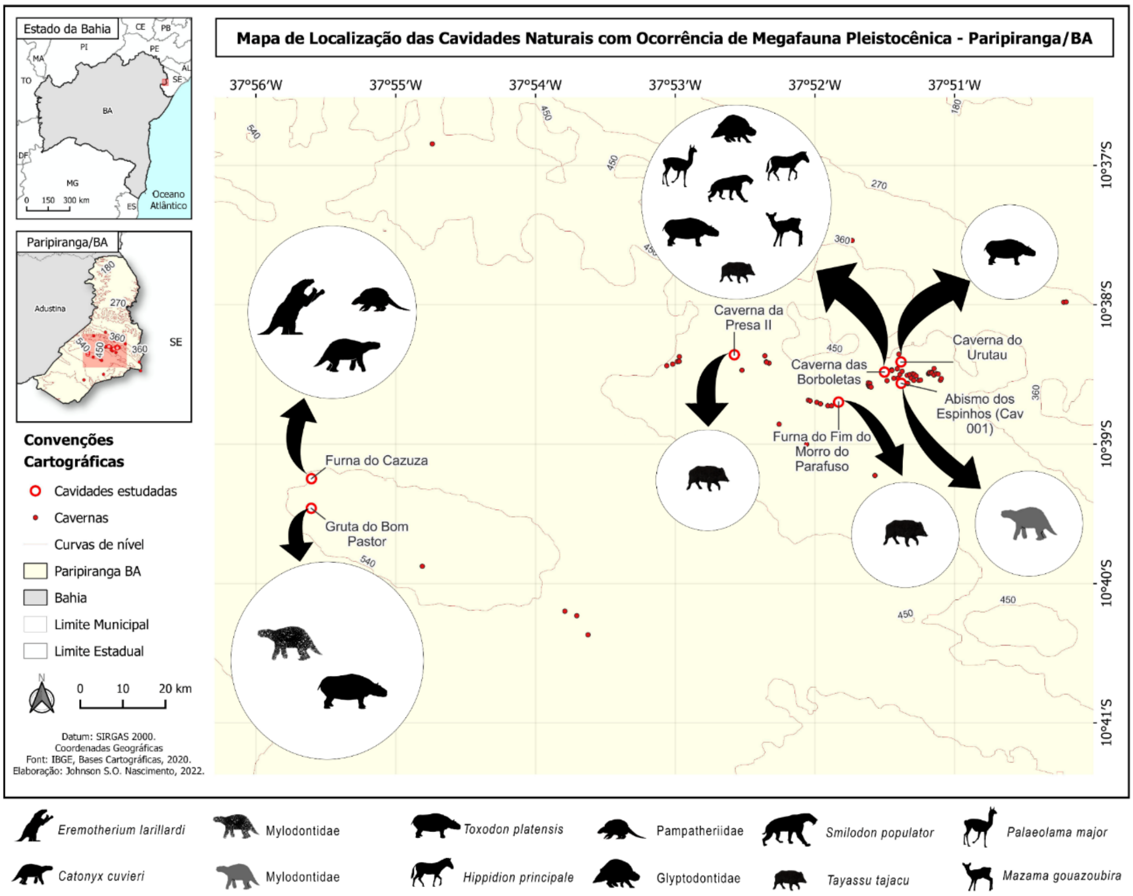

Figure 7. Distribution of Megafauna occurrences in the municipality of Paripiranga.

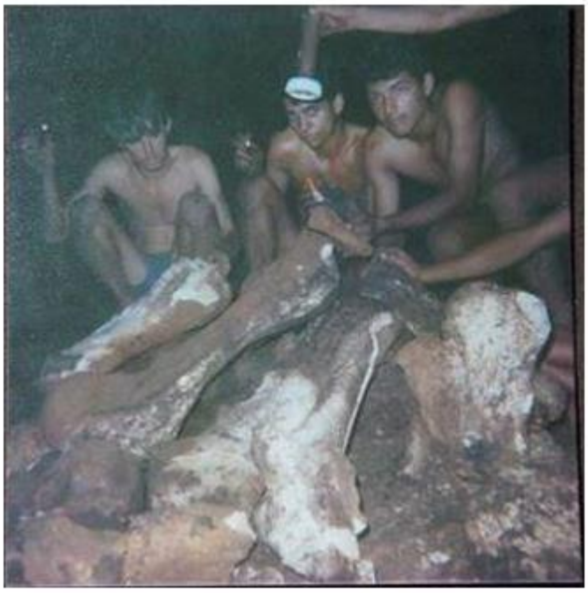

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Figure 9. LIPE team alongside fossils of the giant sloth found inside Furna do Cazuza.

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Table 1. Some characteristics of the cavities visited in the region of Paripiranga, BA.

Natural Cavities	Speleothems	Sedimentology (brief) - Clastic deposits	Remarks
Borboletas Cave	Diversity of Speleothems and Areas of Stalagmitic Crust	These formations consist of blocks, soil, forest litter, and breccias. Fossils of small mammals were discovered, incrusted in flowstone and coralloids	Presence of new taxa, high species richness. Accumulation of recent bones derived from recent water deposition and avian regurgitation.
Furna do Fim do Morro do Parafuso	Remarkable Variety: Flowstones, coralloids, stalactites, stalagmites, paleosols, travertines, curtains, luster, columns, serrated curtains, bacon curtains, paleosols, helictites, calyces, elephant's foot.	These formations consist of soil, blocks, thick packages of breccia containing bones and shells, as well as guano deposits, and exhibit a substantial accumulation of forest litter.	The second-largest cavity in the municipality in terms of horizontal projection, area, volume, and development. It has garnered significant interest from speleological groups such as the Speleological Center of Alagoas (Centro Espeleológico de Alagoas, CEA) and the Subterranean World Speleology Group (Grupo Mundo Subterrâneo de Espeleologia, GMSE).
Urutau Cave	Flowstones, stalactites, stalagmites, columns, travertines, and lusters	Comprising soil, blocks, forest litter, and abundant guano.	In its final chamber, one can perceive ground vibrations while walking and experience an acoustic floor with a distinct "hollow" quality.
Gruta da Presa	Flowstones, coralloids, stalactites, stalagmites, paleosols, travertines, curtains, luster, column, serrated curtains, bacon curtains.	Comprising soil, blocks, and forest litter. The lithology consists of fine-grained, well-stratified calcitic limestone with folds	In this cavity, the first taphonomic studies of vertebrate fossils found within were conducted. Age dating of 560 (years BP) 560±20. Lima, 2017.
Gruta da Presa II	Travertines, stalagmites, stalactites, flowstones, column, curtain bacon, serrated curtain, paleosols	Comprising blocks, soil, forest litter, and breccia.	The lithology consists of fine-grained, well-stratified calcite limestone with folds.

Encanto Cave	Flowstones, coralloids, serrated curtains, numerous travertines, column, stalagmites, stalactites, and clastic deposits consist of soil, blocks, and forest litter.	The cavity does not exhibit large volumes of sedimentary packages when compared to another nearby cavity, e.g., Zumbi Cave.	The lithology is composed of calcit limestone.
Descanso Cave	Flowstones, travertines, curtains, stalagmites, and stalactites	Comprising soil, blocks, and forest litter. Due to its low gradient, the deposition of sediments from the external environment appears to be minimal.	The lithology is composed of calcite limestone.
Zumbi Cave	Flowstones, travertines, curtains, stalactites, curtains, paleosols, and a small occurrence of breccias.	São compostos por solo, blocos e *forest litter*	The lithology is composed of calcitic limestone with various levels of pressure conduits.
Gruta do Bom Pastor	Flowstone, coralloids, stalactites, stalagmites, column, travertine, microtravertine, curtain, luster	Comprising litter urban, forest litter, blocks, soil, and breccia.	The most relevant cave in the Paripiranga karst, with dimensions exceeding 5 times the regional average. It is closely linked to the historical, cultural, and religious identity of the population. The lithology is composed of siliceous limestone, MAXIMUM RELEVANCE.

*forest litter = *serrapilheira*

Table 2. Fossil occurrences in the cavities of the Paripiranga region, BA.

Natural Cavities	Paleontological Presence	Fossil Species	Family	Reference

Borboletas Cave	High and greater diversity of representatives of the megafauna in the region. Noted presence of still-living animals.	*Palaeolama major*, *Hippidion principale*, *Smilodon populator*, *Coendou* sp., *Mazama gouazoubira*, *Toxodon platensis*	Camelidae, Cervidae, Toxodontidae, Felidae, Tayassuidae, Glyptodontidae, Tapiridae, Erethizontidae, Equidae, Testudines.	Nascimento *et al*., 2020
Furna do Fim do Morro do Parafuso	Report on Tayassuid Fossils	*Pecari tajacu = Dycotiles tajacu*	Tayassuidae	Silva *et al*., 2012
Urutau Cave	Occurrence of a bone integrated into the runoff under base B3 - Tooth of *Toxodon* found - Recorded through communication with the local group	*Toxodon* - foi encontrado um dente, o destino do material é desconhecido	Toxodontidae	*Personal communication*
Gruta da Presa	Occurrence of bones from *Tayassu tajacu = Pecari tajacu = Dycotiles tajacu*	*Pecari tajacu = Dycotiles tajacu*	Tayassuidae	Lima, 2017
Gruta do Bom Pastor	Occurrence of two megafauna taxa, deposited in the collection of Laboratório de Paleontologia da Universidade Federal de Sergipe	--	Scelidotheriinae and Toxodontinae	Dantas *et al*., 2008
Furna do Cazuza	Representatives of the megafauna were discovered. Some fossil specimens were taken by local residents, leading to the loss of various information. The research within the cavity continues by the authors	*Eremotherium laurillardi*	Megatheriidae	Nascimento *et al*., 2022

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5 CONSIDERAÇÕES FINAIS

A análise da cavidade natural conhecida como Furna do Cazuza mostrou-se promissora para a compreensão da paleobiota pleistocênica da região nordeste da Bahia, fornecendo insights valiosos sobre a megafauna que habitava essa área durante o Pleistoceno final. A descoberta dos táxons *Eremotherium laurillardi* e *Holmesina* sp. e a confirmação de *Catonyx cuvieri*, juntamente com a utilização da análise cronológica por AMS ^{14}C, permitiu estimar que esses animais da megafauna viveram durante o Pleistoceno Final (36.6 a 7.6 ky cal BP). Ampliando nosso conhecimento sobre a diversidade e distribuição temporal desses animais.

Após atualizar a lista de ocorrências de fósseis de mamíferos (Pleistoceno-Holoceno) coletados em cavidades naturais na região de Paripiranga, Bahia e salvaguardados na coleção de Paleovertebrados do LIPE-SP-MHN-UFAL, salientamos a riqueza de diversidade palebiológica pleistocênica da região. Atualmente são registrados Cervidae (*Mazama gouazoubira*), Camelidae (*Palaeolama major*), Erethizontidae (*Coendou* sp.), Equidae (*Hippidion* sp.), Felidae (*Smilodon populator*), Toxodontidae (*Toxodon platensis*), Pampatheriidae (*Holmesina* sp)., Megatheriidae (*Eremotherium laurillardi*), Scelidotheriidae (*Catonyx cuvieri*) e representantes das famílias Tayassuidae, Glyptodontidae, Tapiridae, Testudines.

A incorporação de espécies citadas enriquece não apenas o registro fossilífero local, mas também contribui para inferências paleoambientais e paleoecológicas mais robustas. Além disso, a análise da dieta isotópica dos táxons estudados oferece uma visão mais clara do ambiente em que habitavam, sugerindo um habitat transicional entre florestas de baixa densidade e zonas de savana arbórea a aberta.

A importância cultural e científica da região não pode ser subestimada ou esquecida. A preservação e divulgação desses achados paleontológicos não apenas enriquecem o conhecimento científico, mas também promovem uma conexão mais profunda entre a comunidade local e seu patrimônio histórico e natural. A proposta de criação de espaços de memória, inspirada em exemplos bem-sucedidos como em Maravilha, AL e Inhapi, AL, podem servir como um modelo para outras regiões, incentivando o turismo científico e contribuindo para o desenvolvimento socioeconômico local.

Por fim, é imperativo destacar a necessidade de um planejamento estratégico contínuo e colaborativo entre a comunidade científica e as esferas municipais e federais. A conservação e valorização do patrimônio paleontológico e espeleológico de Paripiranga, Bahia, requerem um compromisso conjunto com a educação patrimonial e ambiental, visando garantir a sustentabilidade desse legado para as gerações futuras.

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