

*The geoheritage in the north of Tocantins state and southwest  
of Maranhão state, Brazil*

*O geopatrimônio no norte do Tocantins e sudoeste do  
Maranhão, Brasil*

*El geopatrimonio en el norte de Tocantins y suroeste de  
Maranhão, Brasil*

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**Abstract**

The Brazilian territory has a significant and diversified geoheritage, but there is still a lack of knowledge about it, especially in areas far from metropolitan regions, where most of the research is concentrated. In this work, elements of great significance of the geodiversity in the north of the state of Tocantins and southwest of Maranhão are approached. The region is located on the Brazilian agricultural frontier, a fact that makes it important to know its physical-natural diversity and to provide an overview of the importance that some portions of the area have for conservation and sustainable development. In the region, there are significant sites composed of fossils, waterfalls and geoforms that, according to a theoretical review of the themes addressed and the field work, are important for carrying out scientific, didactic and geotouristic activities.

**Keywords:** Geodiversity. Geoconservation. North of Tocantins. Southwest of Maranhão.

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### Resumo

O território brasileiro dispõe de um significativo e diversificado geopatrimônio, mas ainda há carência de conhecimento deste, especialmente em áreas distantes de regiões metropolitanas, onde se concentram a maior parte das pesquisas. Neste trabalho são abordados elementos de grande significância da Geodiversidade no norte do estado do Tocantins e sudoeste do Maranhão. A região está situada na fronteira agrícola brasileira, fato que torna importante conhecer sua diversidade físico-natural e trazer um panorama da importância que algumas porções da área possuem para conservação e o desenvolvimento sustentável. Na região se destacam locais significativos constituídos por fósseis, quedas d'água e geoformas que, de acordo com uma revisão teórica sobre as temáticas abordadas e os trabalhos de campo, são importantes para a realização de atividades científicas, didáticas e geoturísticas.

**Palavras-Chave:** Geodiversidade. Geoconservation. Norte do Tocantins. Sudoeste do Maranhão.

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### Resumen

El territorio brasileño tiene un geopatrimonio importante y diversificado, pero todavía hay una falta de conocimiento sobre él, especialmente en áreas alejadas de las regiones metropolitanas, donde se concentran la mayor parte de las investigaciones. En este trabajo se discuten elementos de gran significación de la Geodiversidad en el norte del estado de Tocantins y suroeste de Maranhão. La región está ubicada en la frontera agrícola brasileña, hecho que hace importante conocer su diversidad físico-natural y brindar un panorama de la importancia que algunas porciones del área tienen para la conservación y el desarrollo sostenible. En la región se destacan lugares significativos conformados por fósiles, cascadas y geoformas, los cuales, según una revisión teórica de los temas tratados y el trabajo de campo, son importantes para el desarrollo de actividades científicas, didácticas y geoturísticas.

**Palabras-chaves:** Geodiversidad. Geoconservación. Norte de Tocantins. Suroeste de Maranhão.

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## Introduction

Geodiversity consists of the natural diversity of geological (minerals, rocks, fossils), geomorphological (physical processes, relief, geoforms), pedological and hydrological features (GRAY, 2013). Therefore, it is the basic component of landscapes and the substrate of all biological activities, and consequently of human actions (GRAY, 2021). Knowing it and valuing it is essential for sustainable development.

Achieving an efficient management of geodiversity requires multiscale and multidisciplinary approaches, as it plays a major role in maintaining ecosystems and generating associated goods and services, *sine qua non* for the natural balance and stability of the lifestyle of human societies (NASCIMENTO, *et al.*, 2008; GARCIA *et al.*, 2021).

The degradation of natural elements and resources, caused by environmental changes resulting from their intensive use, has grown significantly in the northern region of the state of Tocantins and southwest of the state of Maranhão. The increasing development of the cattle ranching and agriculture in the area imposes threats to the conservation of natural environments, and geodiversity is at the base of this whole process (DIAS *et al.*, 2005; BRITO, 2015).

In the north of the state of Tocantins and southwest of the state of Maranhão, the landscape is mainly characterized by outcrops of geological formations of the Parnaíba intracratonic sedimentary basin, by the transition between the Cerrado (Brazilian savanna) and Amazonian domains and also by the presence of monocultures, mainly soybean, and cattle raising (VAZ *et al.*, 2007; HAIDAR *et al.*, 2013).

With these processes of pressure on natural environments underway in the region, it becomes important to know the physical-natural diversity of the area and bring an overview of the importance that some portions of this region have for conservation and sustainable development, thus contributing to the development of management plans and protection of sensitive and relevant areas of geodiversity.

The landscape is the dynamic and unstable combination of physical, biological and socioeconomic elements that, based on perception, characterize a particular portion of geographic space (BERTRAND, 2004). In this work, we will emphasize the physical and abiotic elements of the landscape. With this, this study aims to present the geoheritage in the northern state of Tocantins and southwest of the state of Maranhão, in order to highlight natural elements of significant scenic beauty, didactic-scientific importance and also geotourism in the region.

### Physiographic Context Of The Study Area

The study area (Figure 1) was delimited between latitudes 07° 31' 48" S and 05° 02' 36" S, longitudes 49° 16' 31" W and 45° 55' 22" W, taking into consideration the regions known as Bico do Papagaio in the state of Tocantins, and the Tocantina region of Maranhão, in the state of Maranhão, the area overlies rocks of the western portion of the intracratonic Parnaíba sedimentary basin, with geological formations dating from the Permian to the Cretaceous.

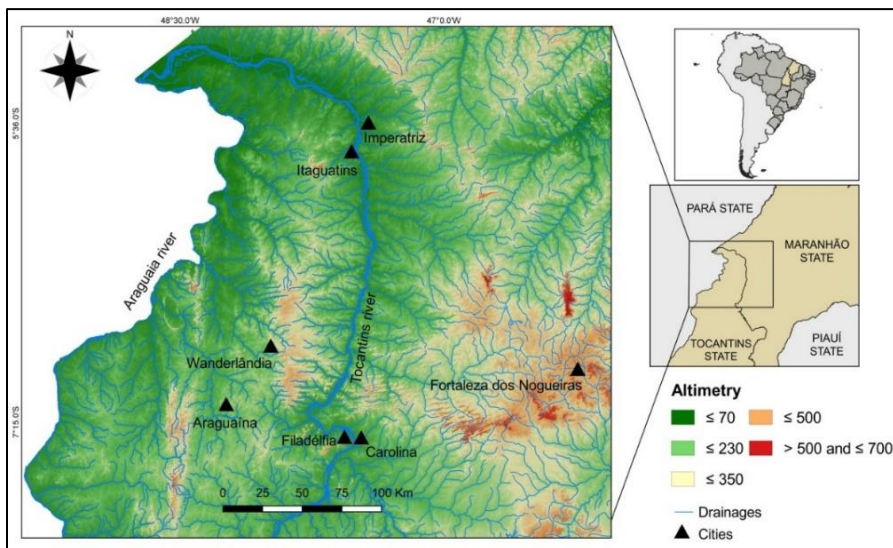
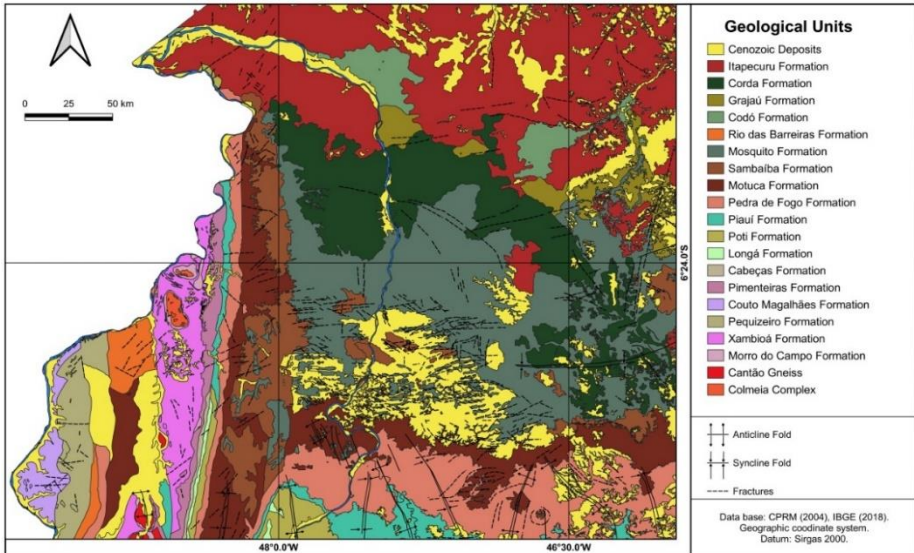


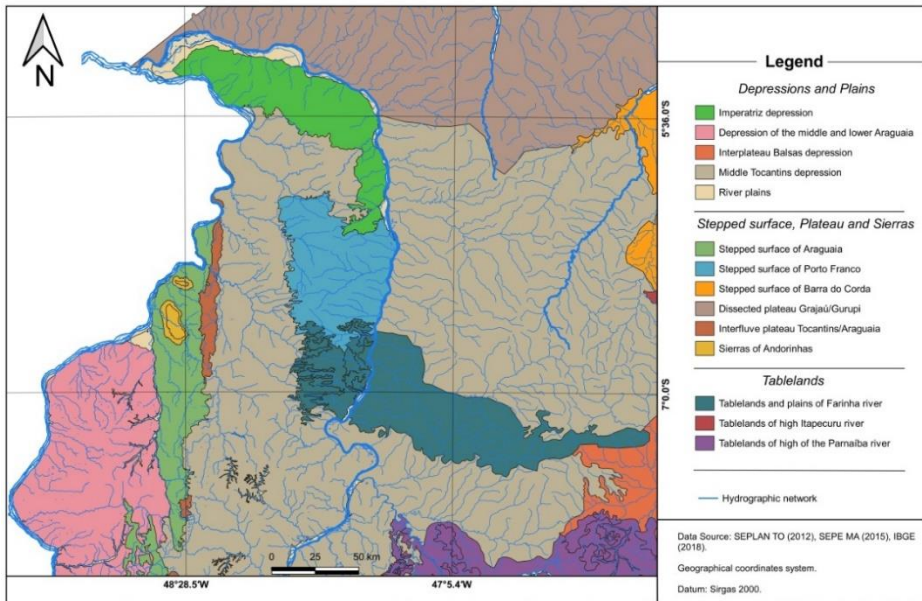
Figure 1: Location of the study area

The predominant geological units (Figure 2) in the region are characterized by the presence of cream to white limestone interspersed with fine to medium grained sandstones in the Pedra de Fogo Formation (Lopingian; PLUMMER, 1948), fine to medium white sandstones, siltstones and shales in the Motuca Formation (Lopingian; PLUMMER, 1948), red to reddish-brown sandstones in the Sambaíba Formation (Triassic; PLUMMER, 1948), basalts in the Mosquito Formation (Jurassic; AGUIAR, 1971), and very fine red, white, purple to very fine gray sandstones in the Corda Formation (Barremian; LISBOA, 1914; AGUIAR, 1971).



**Figure 2:** Geology of the study area

The geomorphology of the study area is characterized by the depressions of the Araguaia and Tocantins (Figure 3), with predominance of river plains and terraces; residual plateaus of the Araguaia-Tocantins Interfluve, with tabular and convex shapes; and the tablelands and plains of Farinha river, a unit popularly known as Chapada das Mesas, with genetic characteristics linked to dissection and mostly tabular and ruiniform forms (TOCANTINS, 2013; MARANHÃO, 2018).



**Figure 3:** Geomorphological map of the study area

The hydrography of the area is marked by the presence of the Tocantins and Araguaia rivers, in addition to a large hydrographic network composed mostly of first and second order drainages. The soils have high acidity, which is common in cerrado areas, and the main soils that occur in the region are the Red Argisol, Yellow Latosol, Red-Yellow and Red, Red Nitosol and Plinthosol (IBGE, 2011).

## Methodology

For the development of the study presented here, a bibliographic survey on the theme and area under study was carried out. There was also the construction of a database about the configuration of the landscape of the region, with vectorial and raster bases processed in the free geoprocessing software Qgis 3.10. Information about the geology of the area at a scale of 1:250.000 was collected in the Brazilian Geological Chart to the millionth scale, in the Araguaia (SB.22) and Teresina (SB.23) sheets, as well as their vectorial data at a scale of 1:1.000.000 generated by the Geological Service of Brazil - CPRM (2004). Geomorphological data at scale 1:250.000 were obtained from the websites of the Secretary of Planning of Tocantins (SEPLAN, 2013) and Secretary of State and Strategic Programs of Maranhão (SEPE, 2018).

Subsequently to the data survey stage, the cataloging of the outstanding elements of Geodiversity presented here was carried out through the Google Earth Pro software and field work. The relevant sites were selected based on the authors' knowledge of the area, choosing outcrops that stand out from the others for their scenic beauty or because they already have scientific papers published, which shows potential

for educational and touristic activities. The field work was carried out to recognize in situ the geosites catalogued in the office work. A final stage consisted of the analysis and interpretation of the data obtained in the previous stages, recognizing values and threats to the outcrops presented.

## Results And Discussion

In the study area, geosites consisting of geofoms, waterfalls, and fossils were identified as relevant for the development of scientific research, educational activities and also for geotourism. Some researchers consider, according to Brilha (2016), geosites only those Geodiversity sites that have scientific value, here we consider geosites all Geodiversity sites that have elements with some significant value, which can be scientific, educational, aesthetic, cultural value or economic, linked to geotourism (GRAY, 2004; 2013).

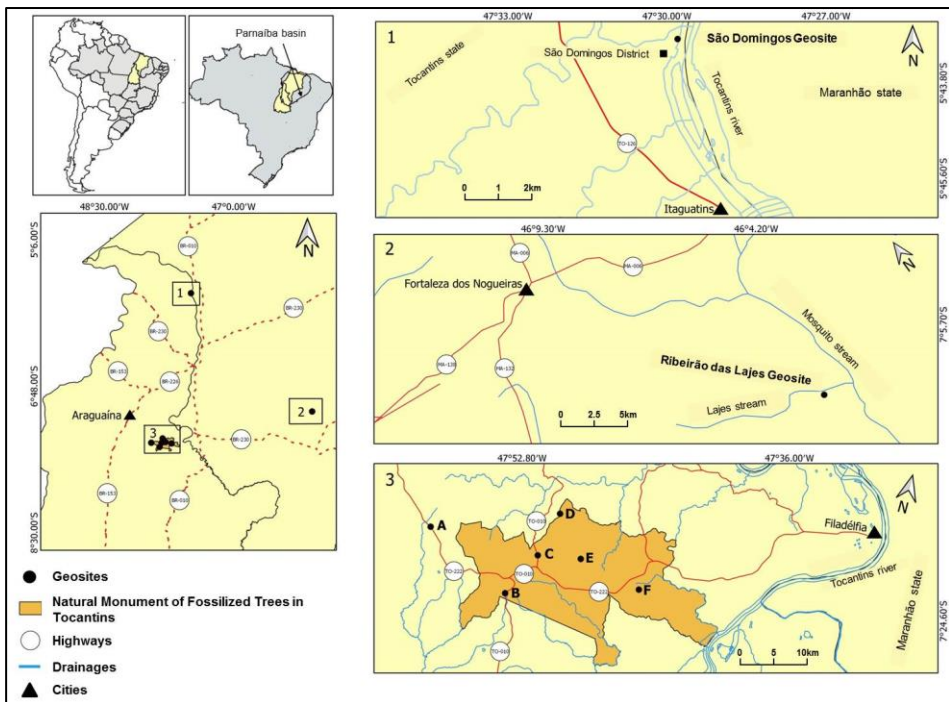
The geoheritage of the north of the state of Tocantins and southwest of Maranhão, inventoried here (Table 1), was divided into three categories according to the element that each geosite has, namely: fossils, geofoms, and waterfalls. In this work, quantitative analyzes of the geosites were not performed, as this is not the objective of the study.

**Table 1:** Preliminary summary of the geosites of significant importance in the north of Tocantins state and southwest of Maranhão

TOCANTINS		
Geosite	Elements of Geodiversity that it has	Location
São Domingos Geosite	Footprints of sauropod dinosaurs	Municipality of Itaguatins
Natural Monument of the fossilized trees of Tocantins	Fossils of gymnosperms and ferns	Municipality of Filadélfia
Tempero Waterfall	Waterfall	Municipality of Wanderlândia
MARANHÃO		
Geosite	Elements of Geodiversity that it has	Location
Ribeirão das Lajes Geosite	Fossil footprints of theropod dinosaurs	Municipality of Fortaleza dos Nogueiras
Chapéu Hill	Geoform	Municipality of Carolina
Chapada das Mesas Gateway	Geoform	Municipality of Carolina
São Romão Waterfall	Waterfall	Municipality of Carolina
Prata Waterfall	Waterfall	Municipality of Carolina

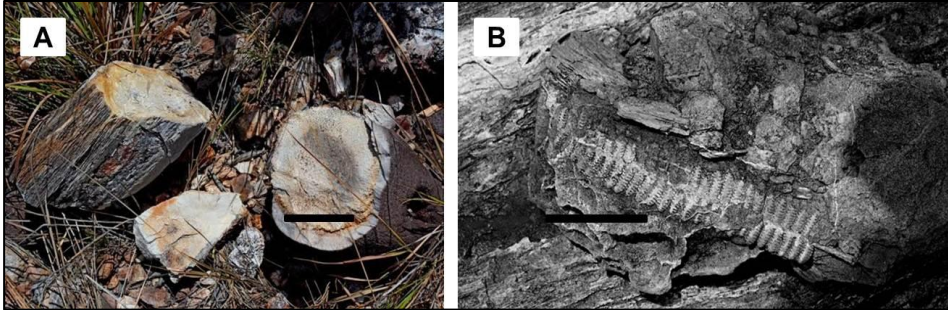
## Fossils

The fossiliferous records found in the study area (Figure 4) consist of gymnosperm trunks and mineralized fern leaves from the Motuca Formation (Permian-Lopingian), municipality of Filadélfia, state of Tocantins; ichnofossils, represented by footprints of theropod dinosaurs (carnivores) in the Sambaíba Formation (Triassic), municipality of Fortaleza dos Nogueiras, state of Maranhão; and ichnofossils, also represented by footprints of sauropod dinosaurs (herbivores) in the Corda Formation (Cretaceous, Barremian), municipality of Itaguatins, state of Tocantins.



**Figure 4:** Location of geosites with fossil presence in the study area. (1) geosite of sauropod dinosaur footprints; (2) geosite of theropod dinosaur footprints; (3) geosites of fossil gymnosperms and ferns. (3A) Fazenda Peba geosite; (3B) Fazenda Vargem Limpa geosite; (3C) Fazenda Andralina geosite; (3D) Fazenda Santa Maria geosite; (3E) Fazenda Grotão geosite; (3F) Fazenda Buritirana geosite

In the municipality of Filadélfia, Tocantins, there are plant fossils attributed to gymnosperms and ferns (DIAS-BRITO *et al.*, 2009). The records (Figure 5) are present in six geosites, forming one of the largest fossilized forests in the world. The wealth of paleobiological records led to the creation of a protected area under the management of the state government, State Law n° 1.179/2000 (TOCANTINS, 2000), for the conservation of this important paleontological record and its use for scientific and educational purposes.



**Figure 5** Permian fossils from Filadélfia, Tocantins. (A) fossilized gymnosperm trunk; (B) fossilized fern leaf. Scale bars 10 cm. Pictures: Alvaro Vallin

The Natural Monument of fossilized trees in the state of Tocantins covers five of the six geosites with fossil presence in the municipality of Philadelphia, the most abundant taxa identified are: *Botryopteris nollii*, *Dadoxylon* sp., *Grammatopteris freitasii*, *Pecopteris* sp., and *Tietea* sp. In this assemblage of phytofossils, arborescent ferns stand out, a vegetation variety abundantly distributed in humid continental environments in the Neo-Paleozoic (KAUFFMANN, 2018), and trunks belonging to conifers, from the pine group, with taxa also found in the Araripe Geopark area (BARRETO, *et al.*, 2020).

These geosites are used for scientific research and educational activities by schools and universities in the region, especially the undergraduate courses in Biology and Geography at the Federal University of Tocantins, Araguaína Campus. The use of this area for geotourism is still limited, needing a better structure to receive visitors and a greater dissemination for it to be known and used in a sustainable way.

In the municipality of Fortaleza dos Nogueiras, state of Maranhão, there is a geosite with the presence of ichnofossils, characterized by tracks of theropod dinosaur footprints (Figure 6). This discovery was reported by Assis *et al.* (2010) for sandstones of the Sambaíba Formation, hitherto considered aphanitic.

The geosite Ribeirão das Lajes is located on the banks of a homonymous stream, in a rural area 22 km from the city of Fortaleza dos Nogueiras. A total of 71 digitigrade tridactyl footprints were recorded, attributed to small and medium-sized theropod dinosaurs (bipeds, carnivores) (ASSIS *et al.*, 2010). Few studies have been developed to classify the specimens at a less inclusive taxonomic level, at the same time, it is also little used for educational activities, thus needing more studies and outreach activities for its sustainable use.



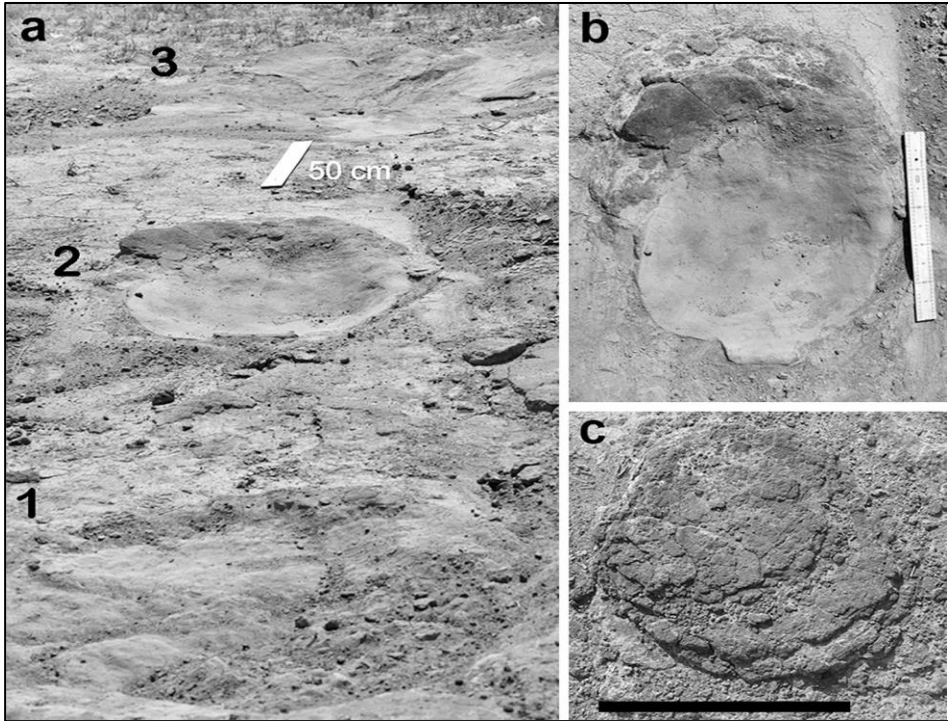


**Figure 6:** Footprint of Teropoda Indet. in Fortaleza dos Nogueiras - MA. Scale bar 5cm. Adapted by Assis *et al.* (2010)

As this is the first report of fossils for a geological unit interpreted as being aphanosiliferous by several authors (e.g. AGUIAR, 1971; MESNER; WOOLDRIDGE, 1964; PLUMMER, 1948; SANTOS; CARVALHO, 2009), studies of the taxonomic and icnotaxonomic nature of the specimens are needed as well as works aimed at the stratigraphic positioning of the ichnofossils, or even a better understanding of the sedimentation and paleoenvironment of this formation, which had its age assigned only by contacts with other geological units.

In the rural district of São Domingos, municipality of Itaguatins, state of Tocantins, there is the occurrence of ichnofossils, represented by footprint trails and isolated footprints attributed to sauropod dinosaurs (DE VALAIS *et al.*, 2015; LOPES *et al.*, 2019; LOPES *et al.*, 2021). The footprints, contained in fine and medium-grained sandstones of the Corda Formation, constitute a set of four “narrow-gauge” tracks related to basal sauropod dinosaurs.

The ichnofossils of the São Domingos geosite (Figure 7) are located on the banks of the Tocantins River and have poor to moderate preservation. Of the seven original trails, described by Leonardí (1994), only four are currently identifiable. Erosive agents have been slowly reaching the rock bearing the footprints, but it is the mechanical force of the river water that descends more abruptly after the construction of the Estreito Hydroelectric Power Plant that has been causing a more accentuated erosive action on the rock in which the ichnofossil traces are inserted (DE VALAIS *et al.*, 2015).

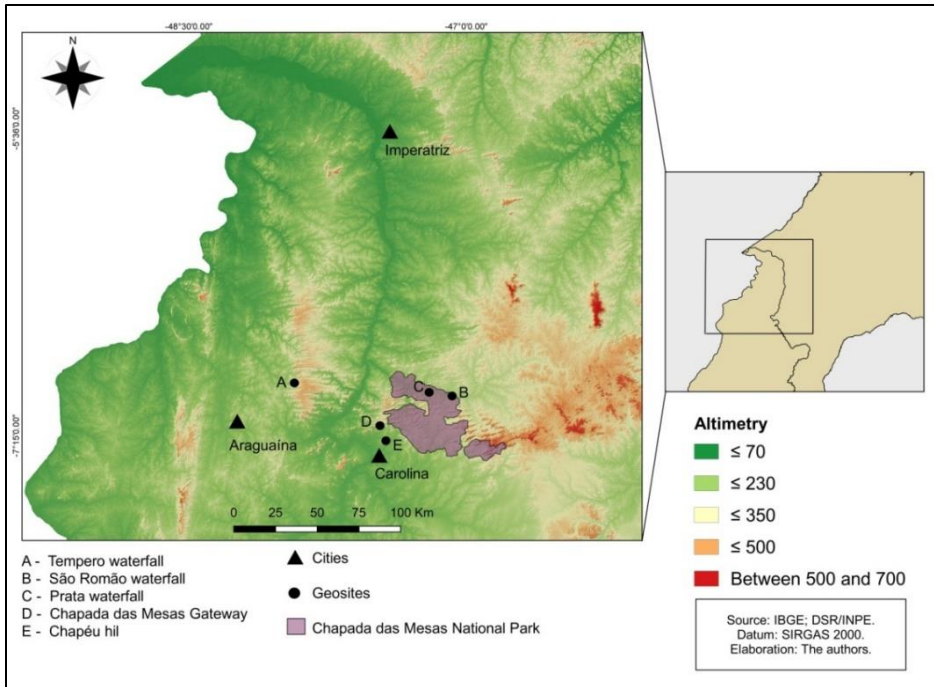


**Figure 7:** In situ tracks of the São Domingos geosite. A trail of three footprints, the nearest trail (a) is covered by modern sediments; (b) and (C) moderately preserved footprints; Scale bars 50 cm. Tavares *et al.* (2015)

Lopes *et al.* (2019) carried out the quantitative analysis of the São Domingos geosite, using the methodology proposed by Brilha (2016) they evaluated the degradation risk, considered high, the potentials for educational and touristic use, considered moderate, and the scientific value that the authors attributed as high. Even with significant potential use and with its elements at risk of destruction, the geosite has no practical conservation activities, with reports of theft of rocks containing inserted footprints by the owner of the area where the footprints are located, a fact that makes it even more urgent to develop legal protection measures for this area.

## Waterfalls

The elements of significant importance of Geodiversity linked to hydrology in the study area, inventoried and presented here, are represented by perennial waterfalls, of tourist interest for its scenic beauty. The waterfalls are in sandstones of the Sambaíba Formation, and they are: the Tempero Waterfall in the municipality of Wanderlândia, Tocantins and the São Romão and Prata Waterfalls, both located in the municipality of Carolina, in the state of Maranhão (Figure 8).



**Figure 8:** Location of geosites of hydrological and geomorphological relevance in the study area

In the municipality of Wanderlândia, state of Tocantins, there is a waterfall known as the Tempero Waterfall (Figure 9). Less known than the others mentioned in this work, this waterfall attracts visitors willing to walk about 4 km on foot to reach the place where it is located. This one does not have any kind of physical structure for visitation, but due to its scenic beauty, it is visited by people who enjoy hiking.



**Figure 9:** Tempero Waterfall. (A) View of the waterfall. (B) sandstone slope on which water flows Pictures: (A) Vanderley Silva; (B) Maykon Wanderson

The Tempero Waterfall is formed by sandstones of the Sambaíba Formation and the Areia stream, its flow is low with some modification in the rainy season. This place has scenic beauty and potential for the development of touristic activities, but still no structure for visitation and consequently no promotion. But there are projects of the municipal government to promote tourism in the municipality using this waterfall as one of the main attractions.

The São Romão Waterfall is located about 70 km from the city of Carolina, Maranhão, and is within the limits of the Chapada das Mesas National Park. The waterfall is made up of very marked cross-stratified sandstones of the Sambaíba Formation, and the waters of the Farinha River.

The Prata Waterfall is located about 60 km from the town of Carolina, and is also situated within the Chapada das Mesas National Park. The geosite is composed of one major waterfall and two smaller ones (Figure 10). The area has basic infrastructure, with a bar, restaurant, leisure area and accommodation for tourists. This waterfall is also formed by the waters of the Farinha River and sediments of the Sambaíba Formation.



**Figure 10:** São Romão and Prata Waterfalls. (A) View of the strip of sand deposited near the São Romão Waterfall. (B) São Romão Waterfall. (C) and (D) Prata Waterfall. Pictures: (A) Fernando Campelo; (B) e (D) Altier Moulin; (C) Torre da Lua ecoturism

Already being used for tourism and well known in the region of the study area, the São Romão and Prata Waterfalls are located on farms in the park area, this is because the protection area was created, but the private properties have not been expropriated and compensated.

These geosites have aesthetic value, for their scenic beauty and also economic value, related to tourism. But geotourism is not yet developed, as this, in addition to the development of recreational activities, is also related to education and environmental interpretation aimed at aspects of Geodiversity, something that still does not occur in these places (MOREIRA, 2014).

## Geoforms

The geoforms reported here are found in the municipality of Carolina, Maranhão. The region has a relief characterized by the presence of plateaus in sandstones with large planar and cross-channeled stratifications of the Sambaíba Formation (ABRANTES; NOGUEIRA, 2013). The relief forms characterized by the presence of several isolated hills, generated from erosive processes, together with the presence of phytophysionomies of the Cerrado domain, form a landscape that constitutes the region known as Chapada das Mesas. An important fact to be highlighted is that the homonymous protected area is not exactly the same geographic area known regionally as Chapada das Mesas.

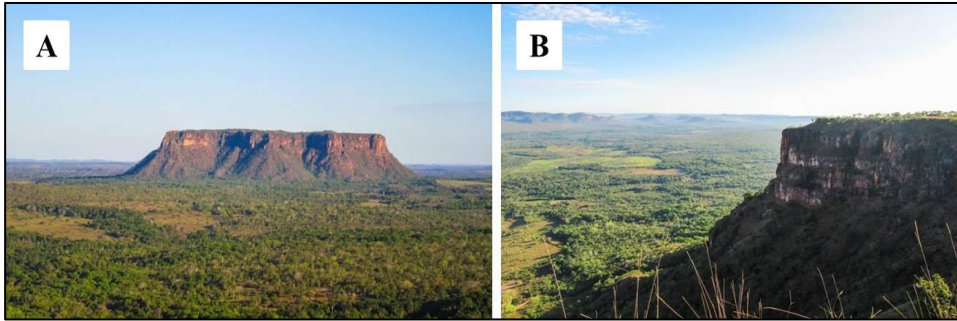
The Chapada das Mesas Gateway is a geomorphological feature consisting of a crack in the rock, giving the perception of a portal (Figure 11). Through the opening in the sandstone it is possible to contemplate a landscape of great scenic beauty, viewing plateaus covered by portions of Cerrado Rupestre.



**Figure 11:** The Chapada das Mesas Gateway. (A) view of the crack in the rock that forms the portal. (B) view of the landscape through the portal. Source: The Authors (2020).

The residual feature is generated by the dissection of the relief through pluvial and aeolian erosion and plateau top weathering, originating the crack called portal. This is one of the most visited places in the region, but there are signs of degradation in the geosite's structure.

Another prominent geoform in the study area is the Chapéu Hill (Figure 12), a plateau visited by people who enjoy adventure tourism and landscape contemplation. From the top of this, which has an elevation of approximately 470 meters, it is possible to see other plateaus of the tableland. Campelo and Ponciano (2018) attribute the formation of the hill to soerguagions of the Parnaíba Basin during the Mesozoic.



**Figure 12:** Chapéu Hill. (A) Panoramic view from Chapéu Hill. (B) landscape of the Chapada das Mesas seen from above the Chapéu Hill. Pictures: Marcelo Nazima

The Chapéu Hill consisted of a plane of greater extension that was worked by erosive processes causing this differentiation in relief. Campelo and Ponciano (2018) reported the evidence of marine sediments of the Pedra de Fogo Formation (Permian) in the outcrops of this geosite, which suggests a contact between this unit and the Sambaíba Formation in the area, making possible the occurrence of Permian fossils in rocks constituting its structure or adjacent.

The geomorphological features presented have scientific value, for the development of research on the evolution of the relief of the region, educational value related to the learning of Geomorphology and Geology, as these are excellent examples of processes and elements that make up the landscape, and also economic value related to geotourism, due to the scenic beauty that these sites present.

Even though these areas already receive visitors, geotourism, with great potential, is not yet developed, since it is also related to environmental education and interpretation in order to relate leisure with geoscience learning to obtain a better awareness of visitors about the importance of the elements and processes that constitute Geodiversity.

It is necessary that these areas become themes of debates in the teaching practice in school environment, thus contributing for the students' knowledge and at the same time for the valorization and promotion of the geodiversity of and in the region. The geomorphological characteristics of the Paleozoic and Mesozoic sedimentary and volcanic sedimentary domains that characterize the Parnaíba Sedimentary Basin are great geotourist attractions because of their scenic beauty. The tablelands, plateaus and ruiniform outcrops form landscapes that naturally call attention, in which the abiotic elements are easily visualized, a fact that shows the great potential of this region for the development of sustainable activities from the economic and environmental point of view.

### **Final Considerations**

The north of the state of Tocantins and the southwest of the state of Maranhão present important sites of Geodiversity interest, their geosites are still being the target of

the first studies, and further research is needed to inventorize, quantify and propose geoconservation for areas with important and sensitive elements of Geodiversity in the region.

This study sought to show some of these significant places, and part of the geosites presented are already within protection areas, including full protection, but without expropriation and compensation for the land, which makes these sites still subject to be used for livestock and agriculture, and in some of them there is the presence of small groups of cattle.

The data found in this study indicate the need to know, value, and appreciate the geodiversity of this region, so that local communities can use it in a sustainable and economically efficient way, thus generating income with activities that conserve the abiotic natural heritage.

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