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INVENTORY AND QUALIFICATION OF THE POTENTIAL OF WATERFALLS IN SERRA DE SANTO ANTÔNIO STATE PARK, MUNICIPALITY OF CAMPO MAIOR, PIAUÍ/BRAZIL

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ABSTRACT:

The Morro de Santo Antônio State Park, located in the municipality of Campo Maior-PI/BR, presents a diverse geodiversity with a variety of geotouristic attractions, highlighting the waterfalls dueto their unique exuberance and intrinsic beauty. This study a imed to i) inventory the water falls of the Serra de Santo Antônio State Park, in the municipality of Campo Maior-PI, from a geotourism perspective; ii) analyze the main morphodynamic processes of the inventoried waterfalls and iii) list their potentials. The inventory was based on Sharples (2002) and Araújo (2021). Six waterfalls were identified: Cachoeira dos Macacos, Cachoeira Buraco do Pinga, Cachoeira Manduzinho, Cachoeira do Escorrega, Cachoeira do Funil and Cachoeira dos Pilões. The morphodynamic processes identified were chemical, physical and biological weathering, rainfall, fluvial, wind, with a predominance of watererosion, differential erosion evidenced by the different stratigraphies of the rocks, etc. As for the potential of the inventoried waterfalls, the following stand out: i) scientific/didactic, ii) cultural, iii) aestheticand, iv) touristic and v) geotouristic. The study reveals the varied potential of the waterfalls of the Serra de Santo Antônio State Park in the municipality of Campo Maior/PI and for the entire Territory of Carnaubais for the purpose of activities related to geotourism.
Keywords: Geodiversity, Geoheritage, Territory of Carnaubais.

INVENTARIAÇÃO E QUALIFICAÇÃO DO POTENCIAL DAS CACHOEIRAS DO PARQUE ESTADUAL SERRA DE SANTO ANTÔNIO, MUNICÍPIO DE CAMPO MAIOR, PIAUÍ/BRASIL

RESUMO:

O Parque Estadual Morro de Santo Antônio, localizado no município de Campo Maior-PI/BR, apresenta uma geodiversidade diversa com uma variedade de atrativos geoturísticos, destacando-se as cachoeiras pela exuberância e beleza intrínseca singulares. O presente estudo teve como objetivo i) inventariar as cachoeiras do Parque Estadual Serra de Santo Antônio, município de Campo Maior-PI, na perspectiva do geoturismo; ii) analisar os principais processos morfodinâmicos das cachoeiras inventariadas e ainda iii) elencar os potenciais das mesmas. A inventariação baseou-se em Sharples (2002) e Araújo (2021). Foram identificadas 6 cachoeiras: Cachoeira dos Macacos, Cachoeira Buraco do Pinga, Cachoeira Manduzinho, Cachoeira do Escorrega, Cachoeira do Funil e Cachoeira dos Pilões. Os processos morfodinâmicos identificados foram: intemperismo químico, físico e biológico, a ação pluvial, fluvial, eólica, com predomínio da erosão hídrica, erosão diferencial evidenciada pelas diferentes estratigrafias das rochas, etc. Quanto ao potencial das cachoeiras inventariadas destacam-se: i) científico/didático, ii) cultural, iii) estético e iv) turístico e v) geoturísticos. O estudo revela o variado potencial das cachoeiras do Parque Estadual Serra de Santo Antônio no município de Campo Maior/PI e para todo Território dos Carnaubais para fins de atividades relacionadas ao geoturismo.
Palavras-Chave: Geodiversidade, Geopatrimônio, Território dos Carnaubais.

INTRODUCTION

Geodiversity deals with the variety of geological and geomorphological environments considered as the basis for the biological diversity of the Earth (Panizza, 2008). It thus comprises the set of natural elements (geological, geomorphological, pedological, hydrological, etc.) arranged in the most diverse forms of environments.

These places where geodiversity has superlative value, constitute what is conceived as geoheritage. This geoheritage for its distinct values presents significant potential for geotourism. Geotourism presents itself as "the tourism that sustains and increases the identity of a territory, considering its geology, environment, culture, aesthetic values, heritage and the well-being of its residents" (Declaration of Arouca, 2011).

The present work aims i) to inventory the waterfalls of the Serra de Santo Antônio State Park, municipality of Campo Maior-PI, from the perspective of geotourism, ii) to analyze the main morphodynamic processes responsible for the sculpture of the inventoried sites and iii) to list the values of their geodiversity.

THE PROMOTION OF GEODIVERSITY THROUGH GEOTOURISM

The initial approaches and the emergence of tourism with a bias towards geotourism began in the 1990s, in principle in European countries, with the contributions of Thomas Hose. His findings stimulated him to make a proposal for dissemination and preservation with a geo[tourist] nature (BENEDICT; RODRIGUES, 2014).

The diffusion of the term geotourism referencing geoconservation for the purpose of disseminating measures of dissemination and sustainable use was strongly addressed by Nascimento, Ruchkys and Mantesso-Neto (2007), Moreira (2008), Moreira (2011) and Hose (2011), given the holding of numerous conferences in recent decades focused on the theme.

Geotourism is conceptualized as "tourism that sustains and enhances the identity of a territory, considering its geology, environment, culture, aesthetic values, heritage and the well-being of its residents" (Declaration of Arouca, 2011).

Bento and Rodrigues (2011, p. 59), highlight the relevance of geotourism in relation to the valorization of abiotic natural elements in the same way as it is carried out with biotic elements:

> The current increase in the number of visits to natural environments, reveals tourist segments that provide appreciation and understanding of the natural landscape. This recent tourist segment seeks to prioritize the natural aspects neglected by ecotourism: geology and geomorphology, such as rock formations, caves, paleontological sites, etc., providing a tourist experience that goes beyond contemplation, adding information about the origin and formation of the places visited.

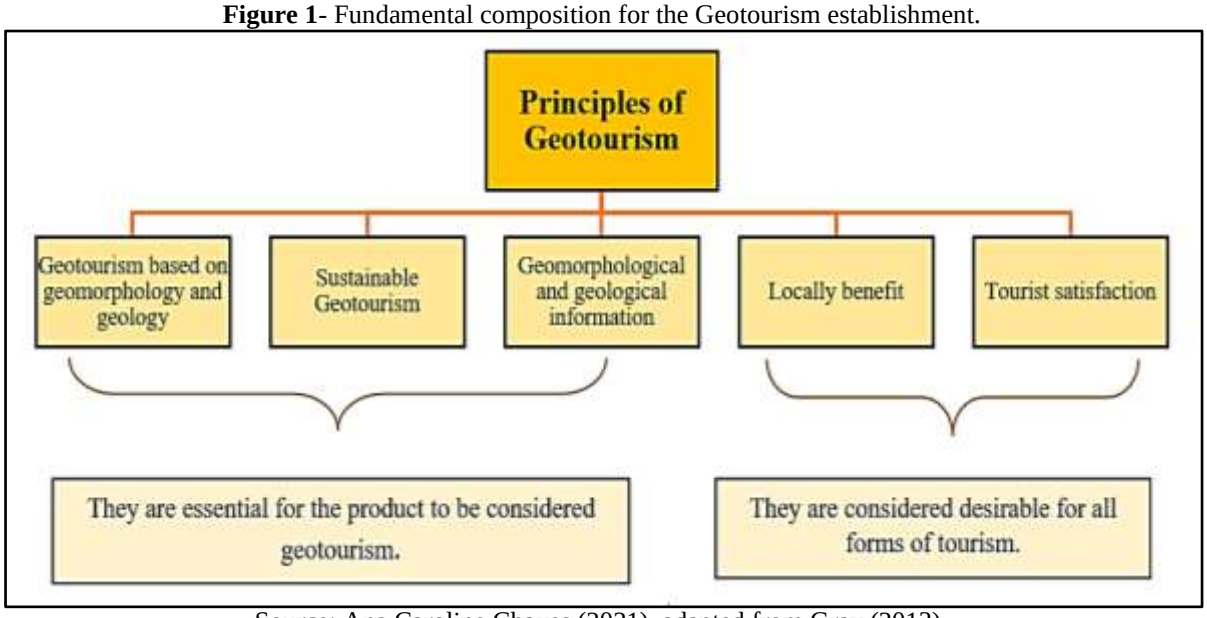
Guerra and Cunha (2006) suggest the valorization of geotourism from geoheritage reconciling the preservation and appreciation of abiotic natural heritage, geological and geomorphological, as well as the magnitude and consequence of the processes of terrestrial dynamics.

For Dowling (2011) geotourism is based on the systematization of the triad: forms (geoheritage, geodiversity sites and elements of geodiversity), processes (depositions, erosion, tectonic procedure, volcanic dynamics) and tourism (units, structures, projects and management).

However, the valorization of the tourism/geotourism potential is completed by social action, supports and equipment for the exercise and appropriation of the abiotic natural heritage, from the understanding of the values imbued in the geodiversity explored.

According to Gray (2011), geotourism is related to nature based tourism. Figure 1 presents the principles essential to the development of geotourism as an activity of valuation of the abiotic natural heritage.

Figure 1- Fundamental composition for the Geotourism establishment.



Source: Ana Caroline Chaves (2021), adapted from Gray (2013).

For Moura-Fé (2015), geotourism presents itself as a form of tourist activity, characterized as a "promising segment of tourist activity", related to geotourism, with specific characteristics and essential to the conservation of geodiversity, in line with several precepts required for "economic development", notably in communities where this activity is practiced.

GEOTOURISM IN THE PROMOTION OF GEOCONSERVATION OF GEODIVERSITY

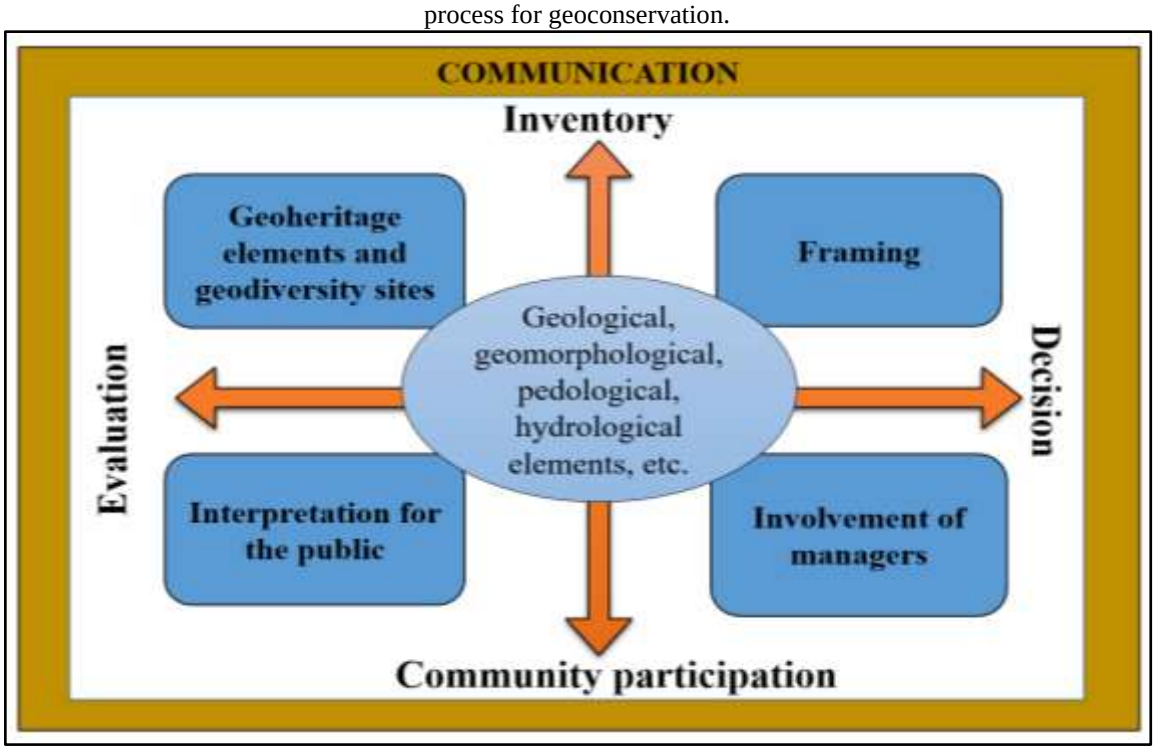
For Jorge and Guerra (2016) geotourism values, highlights the riches of fauna and flora and is independent of conditions, seasons, habits of local biodiversity and can encourage the local economy.

Geotourism encompasses actions of dissemination and interpretation of the natural heritage, which in turn integrate the geological features, geomorphosites, geodiversity sites and elements of geodiversity.

The valorization of geoheritage, sites and elements of geodiversity can occur through the execution of geoconservation actions, these interventions can take place through the exploration of geotourism of areas endowed with scenic beauty.

Geotourism comprises geoconservation strategies of geodiversity, developing in a sustainable way, with actions that promote the knowledge and management of natural resources in a balanced way, with considered use. It involves the exploration of natural elements, with structured management and support of mechanisms that systematize planned actions seeking the preservation and conservation of the environment, as can be seen in Figure 2.

Figure 2- Summary of the relationship of the different phases and purpose of the geopatrimonial evaluation process for geoconservation.



Source: Ana Caroline Chaves (2021), adapted from Tavares et al. (2015).

Geotourism in turn is "tourism that sustains and enhances the identity of a territory, considering its geology, environment, culture, aesthetic values, heritage and the well-being of its residents", UNESCO (2004, cited by NASCIMENTO; MANSUR; MOREIRA, 2015, p.1).

It is noteworthy that geotourism is based on other objectives such as the search for leisure, knowledge and adventure, involving other segments such as ecotourism, cultural tourism and adventure tourism, always exploring the geoheritages, sites and elements of geodiversity concomitant with the sustainable promotion of abiotic natural heritage.

Table 1 summarizes the objectives of some tourism segments that establish relations with geodiversity, such as: geotourism, ecotourism, adventure tourism and cultural tourism.

Table 1- Objectives of some of the geotourism segments that relate to geodiversity.

Tourist segments	Objectives that denote a relationship with geodiversity
Geotourism	Appreciation of the landscape seen from scenic areas, geoconservation, visit and learning of geoheritage, sites and elements of geodiversity.
Ecotourism	Control of geoheritage, sites and elements of geodiversity and biodiversity, and learning activities about the natural heritage.
Adventure tourism	Exploration of geoheritage, sites and elements of geodiversity as support for mountaineering, mountaineering and extreme sports.
Cultural tourism	Management of geoheritage materials, sites and elements of geodiversity with cultural value to society.

Source: Ana Caroline Chaves (2021), adapted from Dowling (2011).

The promotion of geotourism favors the local economy through the sale of various handicrafts, gastronomy and actions to preserve the natural elements that form geodiversity (BENTO; FARIAS; NASCIMENTO, 2020).

MATERIAL AND METHOD

The inventory was based on the *Ad Hoc* technique, described by Sharples (2002), from the identification of the sites considering their potentialities, this possible thanks to the consultation of published materials and videos available on the web, as well as through reports of residents and adventurers knowledgeable in the area. Also noteworthy is the performance of fieldwork.

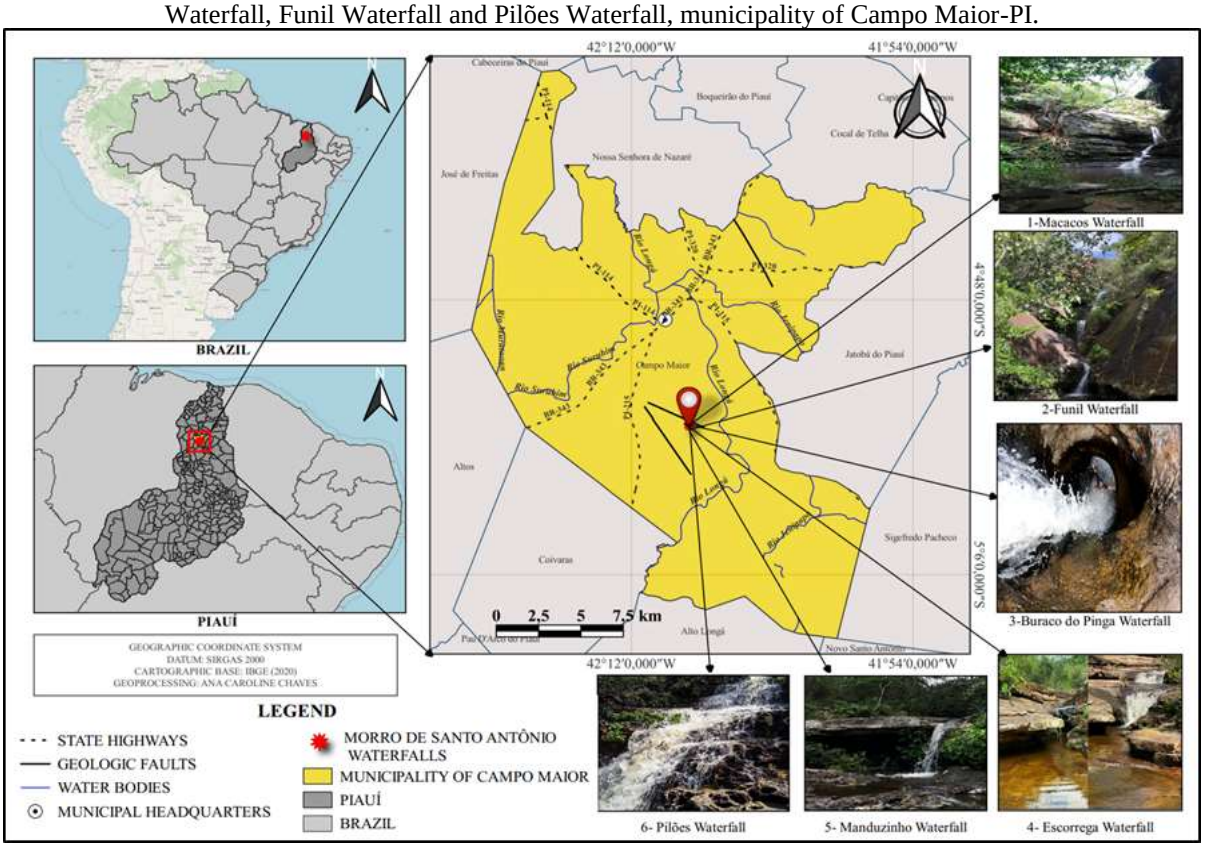
The approach was of the qualitative type from the inventory stage that considered the following phases: i) filling out an identification/characterization form of areas of relevant interest; ii) geomorphological qualification form proposed by Araújo (2021).

RESULTS AND DISCUSSION

The Serra de Santo Antônio State Park located in the municipality of Campo Maior (Figure 3), was created from decree 18,345 on July 8, 2019 presents territorial extension 3,664.03 hectares, is located in the microregion of Campo Maior, being part of the Territory of the Carnaubais, 81 km north of Teresina (IBGE, 2021).

The Territory of the Carnaubais, where the Serra de Santo Antônio State Park is located, presents a relief composed of sedimentary rocks in degradation, with surfaces partially higher in its extension, presenting slightly dissected nuances with contours of tabular hills (FERREIRA; DANTAS, 2010).

Figure 3- Location of Macacos Waterfall, Buraco do Pinga Waterfall, Manduzinho Waterfall, Escorrega Waterfall, Funil Waterfall and Pilões Waterfall, municipality of Campo Maior-PI.



Source: Organization of the authors, 2022. Database: IBGE (2020).

The Morro de Santo Antônio State Park, located in the municipality of Campo Maior-PI/BR presents relevant geotourist interest. The park has 6 waterfalls, all located on the slopes of

Morro de Santo Antônio, in the APP of the Serra de Santo Antônio State Park, rural area, 9 km from the seat of the municipality.

Figure 4 shows the 6 waterfalls inventoried: Macacos Waterfall, Buraco do Pinga Waterfall, Manduzinho Waterfall, Escorrega Waterfall, Funil Waterfall and Pilões Waterfall.

Figure 4- Morro de Santo Antônio Waterfall in Campo Maior/PI.

A-: Macacos Waterfall; B- Buraco do Pinga Waterfall; C- Manduzinho Waterfall; D - Escorrega Waterfall; E- Funil Waterfall; F- Pilões Waterfall.
Source: A- photographs _g.a (2020); B- Lucas Lima(2021); C- Ana Caroline Chaves(2021); D-Rodrigo de Jesus. (2021); E-: Estevam Junior (2021); F- Jéssica Freitas (2021).

The inventoried waterfalls have moderate accessibility, the access route is initially made by the Station neighborhood, in the urban area of the municipality, following the Fazendinha community, passing through the Pineapple Farm to the slope of the hill of Santo Antônio, where it is necessary to carry out circular trail on the slope of the hill through walking to access all the waterfalls.

The rocks where the waterfalls are located are of sedimentary typology with geomorphological content in all waterfalls. There are good viewing conditions, but the lack of infrastructure for the displacement between the waterfalls that has a magnitude compatible with a place (0.1-10 ha) (ARAÚJO, 2021) stands out.

The place has obstacles, the circular type trail on the steep escarpment of the hill restricts the access of some types of public that to the place, for example, people with physical limitations. As for the use stands out the sun and bath tourism, ecotourism, etc., in addition to the current

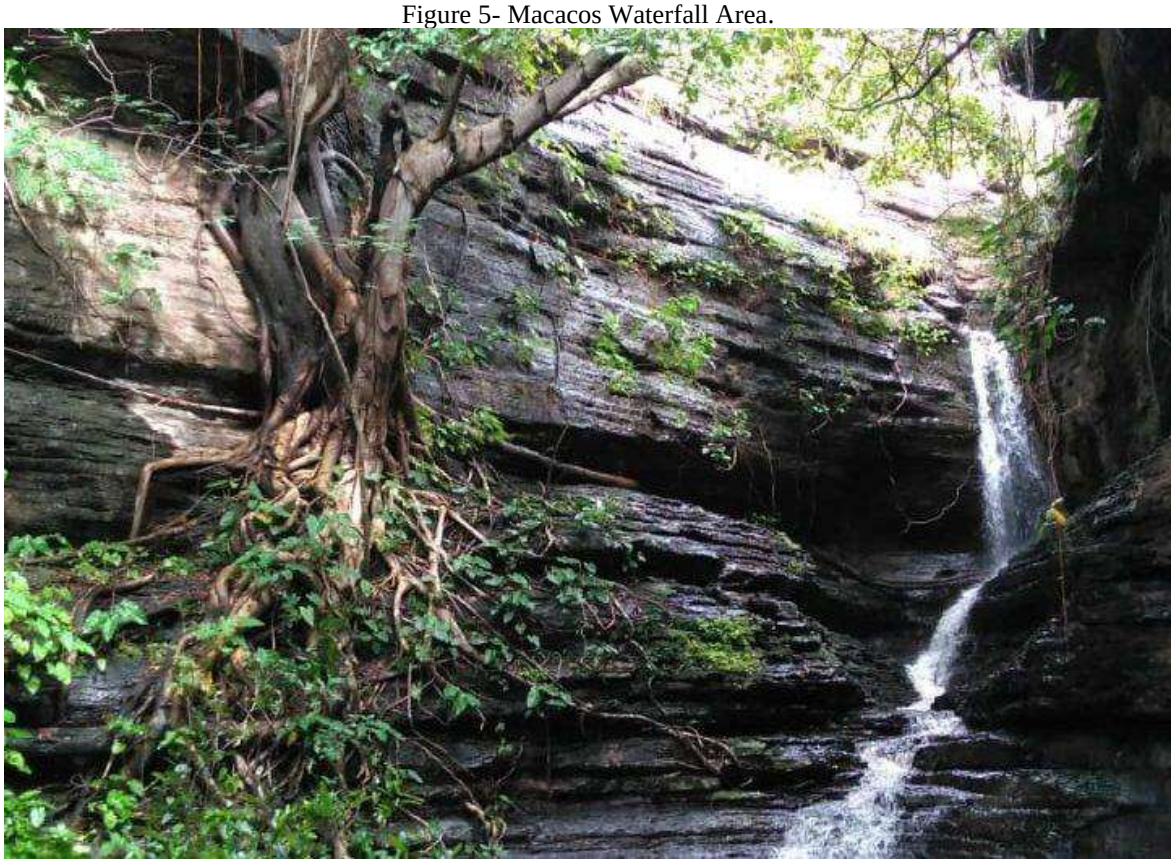
uses, the place offers points of viewpoints, displays potential for geotourism, sports practice, and also the scientific and didactic potential. They will be characterized below.

I- Macacos Waterfall

The Macacos waterfall is a waterfall resulting from a vertical rupture. It is observed strong action of chemical weathering through the corrosion process, biological weathering with action of fixing vegetation cover in the rock, and physical weathering with the presence of fracture and punctual disintegrations of rock, in addition to the differential erosion exhibited by the erosive levels of the rock structure of the site.

According to the morphodynamic processes it is possible to identify the planar or linear stratigraphy in its structure of approximately 10 meters in height (Figure 5).

Figure 5- Macacos Waterfall Area.



Source: Total Geleia Portal (2022).

II- Pinga Waterfall

In Pinga waterfall it is observed the processes of chemical weathering with the corrasão, physical weathering with the presence of pressure relief cracks, water erosion with the presence of lunch boxes generated by the action caused by vertical water flow and mechanical removal, differential erosion that has carved a skylight over time, by the resistance of the rock, through which the water course forms (Figure 6A). The waterfall area still suffers from biological weathering due to the presence of lichens and vegetation cover settled on it (Figure 6B).

Figure 6- Composition of the waterfall of Pinga waterfall.

A- Upper area of the waterfall.
B - Watercourse developed with morphodynamic processes.
Source: Lucas Lima (2021).

III- Manduzinho Waterfall

The Manduzinho Waterfall gets its name due to the name of the ephemeral stream that forms, the main morphodynamic processes related to this waterfall refer to river erosion with the development of furrows, flutes in the direction of the slope, water flow, which combined with chemical weathering performs an incident abrasion, resulting in the formation of channel one of runoff (Figure 7).

These dynamics in the rock composition over the years conditioned the water drainage and the orientation of the water course. There is also a set of conical alveoli, lines and polygonal joints resulting from the dissolution on the rocky slope with expressive wear, in specific places culminating in the formation of rock basins or lunch boxes of varying sizes (Figure 8).

It is also noticeable the laying of cover of vegetables of higher and lower order, favoring the intensity of physical weathering given biological action, observed in Figure 7 referring to the rainy season, predominant in the months of February to April.

Figure 7: Manduzinho waterfall in the rainy season.

Source: Nature Route Portal (2022).

It is observed a significant weathering and erosive process in the referred waterfall, observed by the cavities and horizontal strata of rock that resisted, it is still possible to observe the biological action on rocky substrate.

IV-Escorrega Waterfall

The Escorrega Waterfall is formed from successive waterfalls, composed of steps along the slope of the hill of Santo Antônio, which by morphodynamic processes developed channels where the water forms the bed of an intermittent stream, and which composes the circuit of waterfalls (Figure 8).

Figure 8- Structure of Escorrega Waterfall.

Source: A- Lucas Lima (2021).

The main dynamic processes in the waterfall are equivalent to physical weathering with the presence of fluting, there is a fall of blocks resulting from thermoclastry. The chemical weathering with the wear of the rocks and the biological weathering with effective action of the vegetation cover, favor the erosion processes.

V- Funil Waterfalls

The Funil Waterfall is the largest of the complex, is about 15 meters high, difficult to access, requiring support of instruments for climbing, is composed of three falls that form *jacuzzis*, such as bathtubs carved into the rock, lunch boxes originated from wear promoted by the speed of the water flow.

As for the morphodynamic processes, we highlight the work of abrasion by water erosion and differential erosion and the corrosion forming swimming pools. There is still the abrasion of the water composing alveoli. Biological weathering is present in the entire area that covers the waterfall (Figure 9A and 9B).

Figure 9- Main fall of Funil Waterfall.

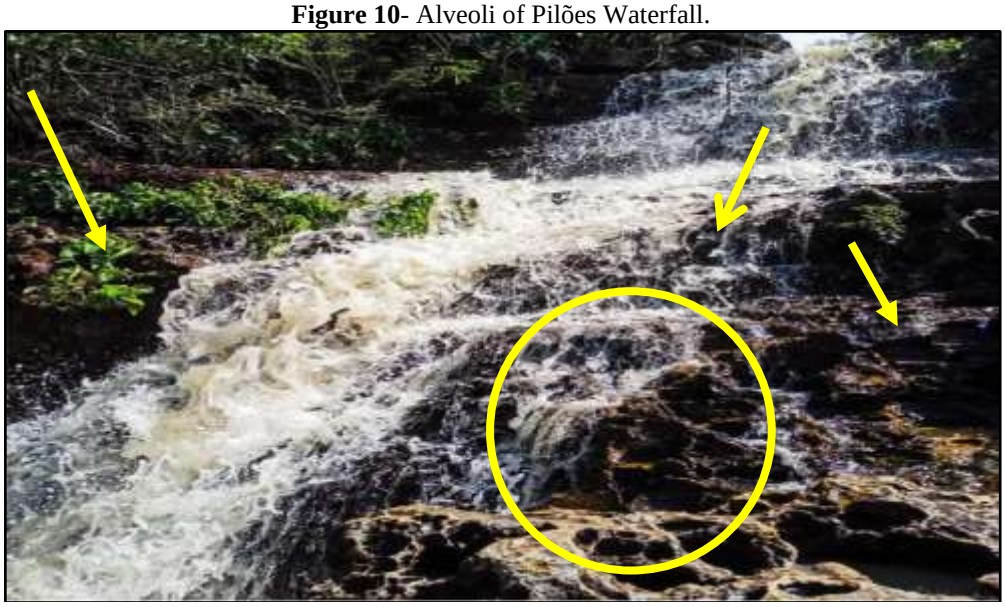
Source: A- Estevam Junior (2021); B-Portal City of Light (2022).

VI- Pilões Waterfall

In Pilões waterfall there are numerous cavities, with varied dimensions, product of morphodynamic action, a factor that justifies the name of the waterfall. Figure 11 highlights in the waterfall the active process of chemical weathering with alveoli through the action of corrosion as well as physical weathering expressed by fracturing lines caused by thermoclasm process, and also action of vegetation cover.

Todos esses processos culminam na erosão na hídrica principal responsável pela formação da cachoeira, como também a erosão diferencial observado pela esculturação composta pela estrutura resistente da rocha (Figura 10).

Figure 10- Alveoli of Pilões Waterfall.



Source: Luan Borges (2022).

All the waterfalls previously inventoried and characterized when some morphodynamic processes are located on the escarpments of a plateau, a dissection feature found in the Serra de Santo Antônio State Park. The main apparent morphodynamic processes are chemical, physical and biological weathering, rainfall, fluvial, wind action, with water erosion and differential erosion.

Figure 11-Solid waste and graffiti identified in the area of Pinga Waterfall in the park.

Source: Ana Caroline Chaves (2021).

In the rainy season with frequent visits some waterfalls, such as Waterfall of Pinga suffers from vandalism actions of graffiti, solid waste (Figure 11) left in its area, in addition to natural order processes.

As for the potential, the following stand out:

i) Didactic/scientific, for thematic approaches of geological/geomorphological interests, environmental and morphodynamic processes, serving diverse audiences of all levels of basic and higher education, the area has several scientific productions between articles, dissertations and book chapters;

ii) Sun/ecological tourism the basis of the tourist activity, explored as an attraction in the environment to be visited should be based on the development of sustainable activities (environmental, socio-cultural and economic) of tourism, the preserved landscape.

iii) Geotourism as a mechanism for diffusion and promotion of geoconservation, understanding of geological heritage, and appreciation of the geoheritage of local geodiversity. From the geological/geomorphological potential and diverse processes in the park, it is possible to observe important elements of the landscape, landforms and their actions, and thus build understanding of the complexity of the dynamics of the area and preserve it effectively.

FINAL CONSIDERATIONS

The inventory made allows us to infer a high potential of the geodiversity of the Serra de Santo Antônio State Park, municipality of Campo Maior, Piauí/Brazil, given the aesthetic beauty and exuberance of the abiotic natural heritage and biodiversity of the park, even though the latter was not the object of analysis in this study.

The different values of geodiversity result in the following potentials identified in the area of study: didactic/scientific, tourist and geotouristic. As for the didactic potential, we highlight subjects of geological and geomorphological interests related to different types of weathering, different types of erosive processes, surface formations, surface hydrology, stratigraphy, rock typology, exogenous agents, etc.

The local potential of the waterfalls inventoried in the park require from the public power and the private initiative actions aimed at i) the valorization and dissemination of local geodiversity, with the implementation of infrastructure that allows the visitation of these places for tourism, ecotourism or geotourism purposes, ii) geoconservation through the promotion of geoeducational actions, iii) planning strategies and State actions for this relevant development territory of Piauí in order to favor local economic development, in sustainable ways in order to improve the quality of life of the populations that inhabit the surroundings of the Serra de Santo Antônio State Park and somehow relate to it.

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