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Application of Geodiversity and its approaches in Pernambuco geopatrimony: a case study¹

Aplicação da Geodiversidade e suas abordagens no geopatrimônio pernambucano: Um estudo de caso

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Abstract: This article provides an identification of the applicability of the concepts of geodiversity, geoconservation, geotourism and geoeducation aimed at the state of Pernambuco, Northeast Brazil. The methodology adopted was a literature review based on consultation of data published on digital platforms, periodicals, event annals and national and international repositories relevant to the topic, within a temporal analysis scale of the last 20 years. It is known that both concepts have gained great relevance in contemporary times within geosciences, geography and related areas, providing a different perspective on abiotic elements and their maintenance and / or conservation for future generations. It is known that a big part of these geodiversity elements allow us to understand the evolution of exogenous and endogenous processes and paleolandscapes, making them true testimonies of the Earth's evolution. The guide principle is the knowledge and / or advancement of the use of these concepts and practices with a view to promoting the territory linked to ecological practices and sustainable tourism.

Keywords: Geoheritage ; Geodiversity ; Pernambuco.

Resumo: Este artigo proporciona uma identificação da aplicabilidade dos conceitos de geodiversidade, geoconservação, geoturismo e geoeeducação voltado ao estado de Pernambuco, Nordeste do Brasil. A metodologia adotada foi a de revisão de literatura baseada na consulta de dados publicados em plataformas digitais, periódicos, anais de eventos e repositórios nacionais e internacionais pertinentes ao tema, dentro de uma escala de análise temporal dos últimos 20 anos. Sabe-se que ambos os conceitos ganharam grande relevância na contemporaneidade dentro das geociências, geografia e áreas afins, proporcionando um olhar diferenciado aos elementos abióticos e a sua manutenção e/ou conservação às futuras gerações. Sabe-se que boa parte desses elementos da geodiversidade permitem compreender a evolução dos processos exógenos, endógenos e das paleopaisagens, tornando-os verdadeiros testemunhos da evolução da Terra. A diretriz norteadora é o conhecimento e/ou avanço da utilização desses conceitos e práticas no viés da promoção do território atrelado a práticas ecológicas e de um turismo sustentável.

Palavras-chave: Geopatrimônio; Geodiversidade; Pernambuco.

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1. Introduction

The Northeast region of Brazil is made up of nine states that have heterogeneous characteristics and landscapes from a natural, social, historical and cultural point of view. It is classified and understood as a very complex, dynamic and variable area from the point of view of abiotic elements and active from the point of view of biotic elements. Therefore, it is a territory with vast elements of geodiversity and biodiversity that need to be measured, evaluated and conserved through their use and/or exploration, as both play a fundamental role in the dynamics of a geoenvironment (a given location of analysis for the study of geodiversity) (ARRUDA, et al., 2023).

The natural environment as a whole is characterized by encompassing all biotic (living) and abiotic (lifeless) elements of the Planet, as well as all processes related to it (GUIMARÃES, 2016). Thus, the living elements present on Earth constitute biodiversity (widely known and disseminated in biology and related areas), while the abiotic elements represent geodiversity (at an interesting stage of development in academia, both in terms of theoretical and methodological evolution, as well as knowledge), inserted in geosciences, geography and related areas that deal with the topic.

Natural landscapes, broadly conceptualized by geology, geomorphology and geographic space, are the result of constructive and erosive processes that provide unique features in relief forms and they often have testimonies that tell their evolutionary history. It is attributed to the genesis of a mountain range even the sedimentary deposits on its slopes. Therefore, geological monuments and geomorphological forms arising from these and other processes, whether mechanical, chemical or biological, represent, individually and as a whole, one of the greatest riches of the Brazilian landscape, for example. Human activities, recently, have also contributed to the modification of the landscape, whether through social, economic, tourist, political or other criteria.

According to literature, all this geological, stratigraphic, geomorphological, pedological, paleontological, hydrographic, hydrogeological, mineralogical variety, as well as other systems, resulting from endogenous and exogenous natural processes and anthropic actions are understood as Geodiversity and underlie the entire heritage of a given environment (BRILHA, 2016; SANTOS, 2016; GUIMARÃES, 2016; ARRUDA, et al., 2022ab; ARRUDA, et al., 2024a). When the criteria and analysis methods are defined and selected, the area becomes a stage for investigation and dissemination of geodiversity and related themes, with the aim of conserving these natural elements in a rational and sustainable way.

According to the concept proposed by Stanley (2000), adopted by the Royal Society for Nature Conservation, these geological-geomorphological features constitute Geodiversity that represents the abundance of elements of natural environments, phenomena and active processes, which result in landscapes, rocks, minerals, fossils, soils and other surface deposits that constitute the foundation of life in the Earth.

As Gray (2004) states, Geodiversity allows natural diversity to be included in conservation, planning, tourism and education through different forms, for example: geodiversity sites, geosites, geological and/or geomorphological heritage, geoparks and areas conserved and/or protected. In 2019, Gray presents a renewed conceptual vision on the insertion of geodiversity in the provision of different types of ecosystem services for contemporary society, previously reinforced by Gray; Gordon; Brown (2013). Arruda et al (2023), conceptualize all this abiotic diversity as a true geoheritage and that both elements, of a scientific, touristic, pedagogical, educational, social, cultural and economic nature, need to be recognized, measured, cataloged and geoconserved (through the practice geotourism and viable geoeducation proposals).

According to Brilha (2005), a geosite is defined as the existence of one or more elements of geodiversity that emerge on the earth's surface, the result of natural and/or anthropogenic actions and that have scientific, pedagogical, cultural, touristic or other value. Still according to the author mentioned above, the Spanish define the term geosite as a synonym for “geotope” or “Place of Geological Interest – LIG”, and which corresponds to the occurrence of one or more elements of geodiversity that outcrop on the earth's surface with delimitation geographical location and the scientific, educational, cultural and historical values attached to it. According to Santos (2012), a geosite (Geotopo) is an area that stands out in geodiversity for presenting exceptional value.

Thus, the focus of analysis of this research is on the state of Pernambuco, one of the states in the NE region of Brazil, which has approximately 187 km of beaches and a total area of 98,149.119 km², subdivided into four sub-regions, They are: coastal (subdivided into the northern, metropolitan and southern sectors), forest zone (subdivided into north and south), wild and hinterland (subdivided into São Francisco and Pernambucano), where there are bays, ridges, lagoons, estuaries, mangroves, natural pools, mountains, high-altitude swamps, depressions, inselbergs, batholiths, plateaus and many other attractions that make the state one of the main tourist destinations in Sol e Praia (coastal area), for example, in the Northeast.

The coastal region, in a general sense, is understood as a space that contemplates these elements of geodiversity in abundance and with a very vast interaction between human and natural actions and is integrated by the scientific

community, based on materials published at regional and national levels. and international, as a geoheritage area (ARRUDA, et al., 2024b), that is, a set of natural elements that, combined with human activities, play an important socioeconomic role in practice, as they are a huge source of resources in exploration and use for local community. It is known that social, cultural and historical processes are encompassed and together they have a unique history and values. And within discussions of geodiversity, these processes allow for environmental planning, territorial ordering and regional development itself when thinking as a whole, in rational and sustainable use, as well as guaranteeing these elements for future generations.

In recent years, this region, the coast, has gained prominence due to its high potential for the study of geodiversity, the multiple areas of geological and geomorphological interest and the vast diversity of abiotic elements combined with very attractive landscapes correlated to local history and culture. It should also be added that many other works were being developed throughout the territory, providing a range of highly relevant research, which will be presented here within a temporal analysis scale of the last 20 years.

Therefore, the research on screen is justified by the understanding of studies in Pernambuco involving the theme of geodiversity and related concepts, with the aim of taking the discussion, already encouraged, to the community in general, in addition to discussing/promoting geoconservation strategies that have already been suggested and are linked to sustainable geotourism for the region. Based on the theme of Geodiversity, this study was carried out in the need to describe the potential of the State of Pernambuco, as well as its Geodiversity elements, and the insertion of the practice of geotourism as an activity of sustainable development and the supply of scientific materials, didactic, informational and technological. It is clear that even with the popularization of geosciences, discussions in some areas of the state of PE still need to be measured, catalogued, inventoried and disseminated to the scientific and local community (formal and non-formal environments).

2. Methodology

We then opted for a vast bibliographical investigation, through unpublished productions, research (articles) published in national/international journals, postgraduate works (Theses and Dissertations) available in national repositories, course conclusion works, pages *online* , Lattes Curriculum, available documents and materials relating to the thematic area, involving the following descriptors 1) geodiversity, 2) geoconservation, 3) geotourism, 4) geoeducation and 5) Pernambuco, with the aim of analyzing the evolution of the theme, which involves geodiversity, within a regional scale for the state in question. It is important to highlight that some works described in some CVs and on websites were not available for *download* on the platforms mentioned. Therefore, it was decided to include the reference “no access” and the justification.

This is a narrative review, of a descriptive-discursive nature, which analyses, interprets and discusses works and research focused on the field of geosciences (geology, geography, paleontology) and related areas. The bottom line is the appreciation of the precursors and the popularization of geosciences throughout Pernambuco.

The theoretical-methodological support of much of the work presented here is based on some of the main researchers on the central theme, such as: Sharples (2002), Gray (2004; 2019) Brilha (2005; 2016), Reynard (2006) , Pereira (2010) and others who contributed to the development of many pioneering works in the region, such as those by França (2015), Santos (2016), Guimarães (2016) and Arruda (2024, in press).

As inclusion criteria, it analyzed academic works and scientific articles published between March 2004 and February 2024, which were only in Portuguese, Spanish and English, and related to the descriptors mentioned above. All work must be associated with the central theme of the research. As for the exclusion criteria, articles published in other languages, works published prior to 2004 were discarded (to date they have not been found), as well as texts that were not associated with the specific objectives on the topic in question, and that were not linked and/or associated with the descriptors already pre-selected. In general, 76 references were obtained that discuss the geodiversity of the state of Pernambuco within this scale of temporal analysis and the previously mentioned objectives.

3. Results and discussion

3.1. Discussion about Pernambuco Geodiversity

In recent years, even with the advancement of many areas of study in geosciences, themes and scientific discussions, such as geodiversity, the number of publications and works is still low taking into account the size of the territory and the

varied natural landscapes that still need be explored, studied, cataloged and conserved in the state of Pernambuco. It is worth highlighting the importance of taking into account within this discussion the importance of understanding the relationship between biodiversity and the geodiversity of a geoenvironment, as both play a fundamental role in local balance, be it natural and/or anthropic. Because, the relationships between these systems enable the variety and complexity of the physical environment as a whole (ASSIS, *et al.*, 2017; ARRUDA, *et al.*, 2017; GUIMARÃES, *et al.*, 2017c).

According to Guimarães *et al.* (2016a), progress in knowledge, appreciation and growth of discussions about geodiversity, its values and direct influence on biodiversity still need to reach many levels. On the other hand, even though biodiversity still has a greater influence and attention to conservation measures, geodiversity has already begun to gain its due place, being highlighted in important projects and programs known worldwide, such as, for example, the UNESCO World Geoparks Program which has geoheritage as one of its main structuring pillars.

The Northeast of Brazil, specifically the State of Pernambuco, is a territory with a vast diversity of biodiversity elements (vegetation aspects, fauna and others) and geodiversity, represented by an infinity of environments with multiple geological potentials, stratigraphic, paleontological, mineralogical, hydrological, hydrographic and geomorphological (GUIMARÃES *et al.*, 2013; GUIMARÃES, 2013; GUIMARÃES & MARIANO, 2014; GUIMARÃES, *et al.*, 2015ab; GUIMARÃES, *et al.*, 2016ab; SILVA, *et al.*, 2016; LIMA, *et al.*, 2016a; GUIMARÃES, 2016; GUIMARÃES, *et al.*, 2017ab; SANTOS, 2016; TAVARES, *et al.*, 2019; SOUSA, *et al.*, 2019; ARRUDA & GUIMARÃES, 2020; ARRUDA, *et al.*, 2021; ARRUDA, *et al.*, 2023).

The beginning of research in the state, involving the theme of geodiversity and tourism, began in 2003 under a proposal for a Caminho das Pedras Project that would provide an inventory and characterization of possible geological sites with tourist potential in the countryside of Pernambuco. The work was published in 2004 entitled “Rural tourism in the countryside of Pernambuco: The path of stones is also of flowers and fruits” written by Geovani Seabra and Gorki Mariano. The objective of this work was to inventory, map and characterize the geological and geomorphological formations of the countryside, in an attempt to develop and propose ecological and rural-based tourist itineraries.

It was only in 2009 that other studies involving geotourism on the south coast of Pernambuco appeared. In 2011, the results of these pioneering studies were the doctoral thesis entitled “Study of the Geological Heritage of Ipojuca/PE as a subsidy for the development of Geotourism” written by Bernadete Negromonte Cavalcante and supervised by Prof. Dr. Valdir do Amaral Vaz Manso linked to the Postgraduate Program in Geosciences (PPGEOC) at the Technology and Geosciences Center (CTG) of the Federal University of Pernambuco (UFPE). Still in the same year, a work was published, authored by França and collaborators (2011), but it is not available for access (justification in Table 01).

However, the peak of publications began in 2012 with the publication of the first master's thesis entitled “Diagnosis of geodiversity and geotouristic potential of the municipality of Bonito, Agreste de Pernambuco” written by Edjane Maria dos Santos and under the guidance of prof. Dr. Gorki Mariano, linked to PPGEOC/CTG/UFPE.

It is worth highlighting that the discussions already focused on areas with great scientific and economic potential and that had the conditions, through a different government perspective, to be known worldwide. It is important to emphasize that some of these spaces belonging to the territory under discussion are potentially favorable to becoming Geoparks under the seal of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

It is noteworthy that among the proposals already presented by the Geological Survey of Brazil – CPRM for the state are: Geopark Arquipélago Fernando de Noronha, Geopark Vale do Catimbau (these already comprise areas recognized as Conservation Units) (SANTOS, 2012 p.28) and Geoparque Litoral Sul de Pernambuco, the latter with a more detailed inventory by Guimarães (2016), in which both have the objective of geoconservation of geoheritage and the promotion of sustainable geotourism.

With the expansion of the idea of creating geoparks around the world, in the conservation of abiotic elements, Nascimento and collaborators (2012), propose the creation of the Geopark South Coast of Pernambuco, cataloging around 23 geosites in more than 363 km² of area. For the authors, the territory has a geological and geomorphological heritage of singular beauty, resulting from the natural processes that occurred throughout the history of the Earth, mainly from the Cretaceous period (around 120 million years ago) to the present day. Still according to them:

The region exposes magmatic and sedimentary rocks that are part of the Pernambuco Basin, whose geological record can be observed in the various forms of relief or rock exposures made up of basalts, trachy-andesites, trachytes, rhyolites, some occurrences of ignimbrites (pyroclastic volcanic rocks), Cabo Granite (rare granite of Cretaceous age in Brazil), as well as conglomerates, sandstones, siltstones, mudstones and limestones. There is a strong tourist appeal in the region mainly due to the scenic beauty found especially along the coast (NASCIMENTO, *et al.*, 2012, p. 649).

The south coast is the region that grows the most in terms of urbanization rates, in coastal areas, in the Northeast. Therefore, the government needs to take a closer look at the management of these areas that can become vulnerable due to real estate speculation. In this way, these coastal areas are characterized according to their unique, attractive and territorial planning elements. Of the entire state of Pernambuco, the South Coast/PE is the most significant area in work involving the discussion of geodiversity and biodiversity (LIMA, et al., 2016b). There are more than 7 works developed in the area and all of them propose the development of geotourism and rational educational practices, aiming to form citizens aware of the natural environment.

Still for this region, Guimarães (2016a), shows that the geology of the South Coast allows us to identify and understand the importance of certain outcrops that are true testimonies and markers of the evolutionary history of planet Earth, such as the breakup of the Gondwana megacontinent. In the study area there are rocks belonging to the Pernambuco Sedimentary Basin, the Ipojuca Magmatic Suite, and the crystalline basement of Neoproterozoic age.

In a large part of the coastal strip of Pernambuco, it is possible to identify the presence of recent sediments, of Quaternary age, resting on the oldest geological units. Being identified in the literature as Pleistocene marine terraces, Holocene marine terraces, Flúvio Lagunares sediments, beach sandstones (beachrocks), beach sediments, alluvial sediments and mangrove sediments, and located along the coastal strip, estuaries and rivers (CPRH, 2001, MADRUGADA FILHO, 2004; PFALTZGRAFF, 2007; BRASIL, 2010; BARRETO; POLCK, 2021).

Guimarães et al (2016B), present the beach sandstones of the South Coast (eachrocks), as true testimonies of maritime fluctuations, marine aggression and regression, linked to human potential since the colonial period, as construction material for churches, fortifications, tombstones, roads and sidewalk paving, among others. It is clear how abiotic elements are intertwined with historical and cultural aspects, through spatial roughness, for example.

The geological configuration of the South Coast of Pernambuco, as well as its relief forms, is largely due to magmatism that occurred in the Cretaceous, giving it a landscape quite different from other areas of the State's coast. Geological diversity and its main occurrences are directly related to the last stage of fragmentation of the ancient Gondwana continent, which resulted in the formation of the African and South American continents. Rocks from the Pernambuco Sedimentary Basin, volcanic and plutonic igneous rocks associated with Cretaceous magmatism and Neoproterozoic rocks from the crystalline basement emerge in the region (GUIMARÃES, et al., 2017a).

Still in the southern portion of the Pernambuco Coast, we find the volcanic *Neck* that is inserted in the Ipojuca Magmatic Suite and intrudes the Pernambuco Sedimentary Basin (ARRUDA & GUIMARÃES 2016; GUIMARÃES, et al., 2017b). From a geomorphological point of view, it is located in the Morphoclimatic Domain of the Mares de Morros (AB'SABER, 2003). That *Neck* of lava, also called Ipojuca Rhyolite as it is known by local residents, is located on the lands today of the Ipojuca Plant (NASCIMENTO, et al., 2012). It is a LIG - Place of Geological Interest, which has a relatively rare formation in the country. According to works published on this point, the need for geoconservation emerges. Despite its geological and geomorphological relevance, little is seen in conservation actions. In this sense, it is initially proposed to raise awareness and subsequently encourage the practice of geotourism, which should be guided by the principles of interdisciplinarity and sustainability aimed at the formation of social, economic and educational interests (SILVA, et al., 2016).

Only one work was found on the coast of the Metropolitan Region involving fossiliferous rocks and a geotourist route . Barreto and Polck (2021), developed a itinerary, taking into account the physical, historical and cultural aspects and that the analysis points were easily accessible to the public, providing sustainable tourism. In this research, sedimentary rocks and their respective fossils were found and highlighted: Lioz limestone (*Rudistas † Radiolites and † Caprinula*), beach sandstones and limestone from the Gramame Formation with bivalve molluscs. Thus, the dissemination of these elements based on the theme of geodiversity allowed a new tourist and educational vision added to the geoscientific value and the attractive availability of the analyzed and publicized spaces.

The North Coast/PE, on the other hand, presents attractions of scenic beauty; mining; geological, geomorphological, paleontological, paleoenvironmental and other notable features, added to historical-cultural and didactic-scientific values that have not yet been investigated and/or explored, except for the K-Pg Mina Poty Geosite in the municipality of Paulista, which has a conservation proposal of geological heritage in an active mining area, under the active responsibility of the private sphere. This geosite, in particular, is recognized worldwide as a natural heritage that keeps records in its soil (the anomalous presence of iridium – coming from the meteor) of one of the most important events in Earth's history: the end of the era of the dinosaurs. For Shyu (2022), “the Poty mine geosite is an example of pre- and post-catastrophe marine sedimentation, recording two types of paleoenvironments in its stratigraphy”.

Through studies at the site, geological and paleontological evidence was found, through the existence of microspherules (microscopic glass grains) and the presence of fragments of impact quartz, produced by the heat generated at the time of

the collision in the Gulf of Mexico that walked and it was deposited here and in other parts of the world, corroborating the idea of a great meteor impact, which characterized the transition between the Mesozoic Era (Age of Dinosaurs) and Cenozoic Era (Age of Mammals). It should be noted that even though it is a private area and full of regulations/guidelines, visits and development of scientific and academic studies are permitted.

For the North Coast, there are some pertinent and highly relevant works involving geology, geomorphology and tourism practices. However, discussions involving geodiversity linked to conservation and geotourism criteria are still scarce. Arruda *et al.* (2022a), proposed for the municipality of Paulista (North Coast) the application of a geodiversity index in an attempt to promote knowledge, associated with the dissemination of this type of mapping as a tool to support regional geodiversity studies. For the authors, the municipality already contains a cataloged geosite (K-Pg Mina Poty) and which has areas of great geodiversity interest, namely: the sandstones of Paulista, for example, which need to be cataloged, quantified and georeferenced in an attempt to promote tourism and development of the local economy.

In the Mata Pernambucana area, there are no published works or geosites cataloged on the available platforms. For the rural region of Pernambuco, the first work at the master's thesis level was that of Santos (2012), who presented a diagnosis regarding the geodiversity present in Bonito/PE, in addition to identifying the local potential for the implementation of geological-based tourism (geotourism). The city is a tourist attraction with many elements of geodiversity, namely: waterfalls, walls and rocky valleys combined with very distinct biodiversity with unique elements of the Atlantic Forest biome.

The second work in the region and the first doctoral thesis for the state was authored by França (2015) who analyzed the municipality of Lagoa dos Gatos. According to the author, the area has a rich scenario, both in terms of geodiversity and biodiversity, where 14 geosites were inventoried and quantified. The research assigns values in an attempt to quantify their potential uses, threats, and vulnerability of each of these.

Some time later, Santos (2016), defended it in his thesis work, continuing his research, focused on the Agreste de Pernambuco mesoregion as an area of rich geodiversity, composed of environments of igneous, sedimentary and metamorphic lithology, possessing rare features. beauty and intriguing genesis. The author also states the need for these areas to be truly used as true “outdoor laboratories” for research, teaching and popularization of Geosciences. The lack of direct opportunities ends up generating underutilization, and often destroyed due to a lack of knowledge about their real importance.

In the countryside of Pernambuco, we also find the geosite known as Parque da Pedra Furada, which is located in the municipality of Venturosa, approximately 249 km from Recife. Geographically, it is between the Agreste mesoregion and the Ipanema Valley microregion. The Alagoinha batholith, as it is scientifically known, has a unique scenic appeal, its outcrop area corresponds to 220 km², with the stone arch being the most conspicuous geomorphic feature , which extends over the slope of a residual hill over the granite (ARRUDA; GUIMARÃES, 2015b; OLIVEIRA, *et al.*, 2016; ARRUDA, *et al.*, 2017).

According to the literature, this feature is attributed to a characteristic development due to differential erosion. The fracture planes suggest that they were caused by pressure relief, in line with the action of erosive agents, are the primary factors that, acting together, resulted in the development of this morphology until the present day. The rocks of Pedra Furada Park, over the years, gain new morphological features. In this way, the geoconservation of this landscape of geomorphological and geological interest is proposed through incentives (MARIANO, *et al.*, 2012). This geomorphological feature alone brings together more than five published works within the theme (Table 01).

Still in the countryside, specifically in the municipality of Brejo da Madre de Deus, we find in the local landscape the formation of tanks (dissolution lunchboxes) which are depressions excavated in the granite rock and can have irregular contours, often controlled by structural features (e.g. . fractures). They have served as data sources for the paleoenvironmental and paleoclimatic reconstruction of the landscape in recent years by geomorphological science, based on studies of the sedimentary and fossil record that fill them. And in recent decades it has inspired the development of work aimed at geoconservation and paleoenvironmental and paleoclimatic reconstruction of these elements (ARRUDA, *et al.*, 2022; LIMA, *et al.*, 2022; ARRUDA, *et al.*, 2023). Only the characterization of this area of interest in geodiversity has brought together 04 works (2 articles and 2 expanded abstracts) and a master's thesis in the last 4 years.

In the backlands of Pernambuco, there is some work focused on the geotouristic potential of the River Islands of the Sub-middle São Francisco (GAMA, *et al.*, 2021) and the inventory of some mountains, hills, hills and vegetated dune fields (SOUSA, *et al.*, 2018). The municipalities of Araripina and Exu are the most mentioned in data and published scientific works, as the Araripe Geopark is located in the region (recognized by the Global Geoparks Network, under the auspices of UNESCO, as the first Geopark in the Americas). They were not cited or cataloged in this research, as the central aspect is directed to the state of Ceará. It should be noted that UNESCO today recognizes six Brazilian geoparks, namely: 1)

Araripe (2006), 2) Seridó (2022), 3) Caminhos dos Cânions do Sul (2022) , 4) Caçapava (2023) and Quarta Colônia (2023) and recently Uberaba (2024).

Several other researches have been carried out in recent years within the state of Pernambuco. The southern coastal zone was and is very privileged with studies involving the theme of Geodiversity. UFPE has a Research Group entitled Geodiversity of Pernambuco (available at: <https://dgp.cnpq.br/dgp/espelhogrupo/5741181411066849>) in partnership with the University of Pernambuco (UPE) that seeks to encourage discussions regarding topic under discussion. It is noteworthy that the group created an online website to further popularize discussions on the key theme of this research. According to Arruda et al (2024b):

The electronic page's key objective is to provide society with information about Pernambuco's Geoheritage with means of dissemination, focused on the biotic and abiotic elements of the state, through published and ongoing work, professionals involved, routes, itineraries and maps. (...) The page offered is non-profit and its ethical and academic values are linked to the Sustainable Development Goals (Arruda, et al., 2024b).

UPE Campus Petrolina currently has a research group titled in Geodiversity, landscape and heritage (available at: <https://dgp.cnpq.br/dgp/espelhogrupo/2168848993938446>), and much of its work is linked to Pernambuco hinterland. It is noteworthy that with the emergence of the Geoeducation , Geocommunication and Sustainability Studies Network (REGECOS), a study group, also from UPE, the popularization of the topic in Agreste and Sertão increased significantly. The municipality of Maracáipe (South Coast) and Petrolina (Sertão) are the cities that have the most published works. The table below describes the latest works published between 2004 and 2023 and the objectives that were included in each research.

Table 01 – Works published within the last 12 years involving the theme of Geodiversity and its applicability to the State of Pernambuco.

TITLE	AUTHOR(S)	YEAR	GOALS
Rural tourism in the countryside of Pernambuco: the path of stones is also one of flowers and fruits	Seabra, G; Mariano, G.	2004	Inventory, map and characterize the geological and geomorphological formations of the rugged region of the state of Pernambuco, to prepare ecological and rural-based tourist itineraries.
Study of the geological heritage of Ipojuca/PE as a subsidy for the development of geotourism	Well, BNC	2011	No access. – <i>Justification</i> : Not available in the University repository.
geoconservationist proposal for the municipalities of Cupira and Lagoa dos Gatos - PE	France, LFO; Mariano, G.	2011	No access. – <i>Justification</i> : Symposium Proceedings website under maintenance.
Diagnosis of geodiversity and geotouristic potential in the municipality of Bonito, rural Pernambuco	Santos, EM	2012	It presents a diagnosis regarding the geodiversity present in Bonito, in addition to identifying the local potential for the implementation of geological-based tourism (geotourism).
Paleontological Heritage and Geoconservation of the Santana Formation (Lower Cretaceous of the Araripe Basin, Pernambuco and Piauí - Northeast Brazil)	BARRETO, AMF; et al.,	2012	Present an inventory and actions to preserve the heritage.
Inventory and quantification of the geosite: granite arch –	Mariano, G., et al.	2012	It describes the occurrence of the only granite arch known to us and warns about the damage caused as a result of disorderly tourism. It presents an

Parque da Pedra Furada - Venturosa/PE			inventory and quantification of the geosite , proposals for strategies for conserving geological heritage and encouraging geotourism.
Southern coastal geopark of Pernambuco (PE) – proposal	Birth, EVIL	2012	It presents a technical and diagnostic study to support the proposal to create the Geopark South Coast of Pernambuco, taking into account the exceptional nature of the geological heritage found, associated with biological, tourist, cultural and historical aspects.
Geodiversity vs Biodiversity: relationships between lichens and windstone in the municipality of Lagoa dos Gatos-PE	France, LFO; et al.	2013	No access. – Justification : Symposium Proceedings website under maintenance.
Course training proposal for tour guides with a focus on geotourism	France, LFO; et al.	2013	No access. – Justification : Symposium Proceedings website under maintenance.
Geoconservation: mapping, description and proposals for disseminating geotouristic trails in the Armando de Holanda Cavalcanti Metropolitan Park, Cabo de Santo Agostinho-PE, Brazil	Guimarães, TO	2013	Highlight the importance of disseminating and conserving the geological, geomorphological, environmental and historical elements of the area, as well as its geotouristic potential .
Geodiversity of the municipality of Araripina – PE, Northeast Brazil	Arruda, KEC	2013	Map the geodiversity of the municipality of Araripina – PE through the application of a methodology that aims to evaluate all components of Geodiversity, avoiding overestimating any particular component.
Survey of the geotouristic potential of the Catimbau National Park – PE as a subsidy for the creation of a future geopark	Silva Junior, ED	2013	Analyze how the survey and mapping of places of geological interest can help in the conservation and dissemination of this wealth, thus contributing to the future creation of a geopark in the region, ensuring the maintenance of part of the Earth's history present in this place.
Pedra Furada de Venturosa, PE: rare granite arch with diorite enclaves	Mariano, G., et al.	2013	This granite arch, called “Pedra Furada de Venturosa”, constitutes a special geomorphological site, linked to the inventory of Brazilian geosites carried out under the aegis of the Brazilian Commission of Geological and Paleobiological Sites -SIGEP.
Geodiversity as a tourist attraction in Brazilian national parks and state parks in the states of Paraná and Pernambuco	Manosso , FC, et al.	2014	Analyze the attractions existing in Brazilian National Parks and State Parks in the States of Paraná and Pernambuco and quantify the attractions based on a classification between contents associated with geodiversity, biodiversity and historical and cultural aspects.
Geotourism and environmental interpretation	Moreira, J.C.	2014	Demonstrate that a greater understanding of our geological heritage is necessary and can be facilitated through the appropriate transfer of information regarding environmental interpretation and the carrying out of geo-educational and tourist activities.
Geodiversity of the state of Pernambuco, Northeast Brazil	Ferreira, B.	2014	Contribute to the identification and characterization of Pernambuco's Geodiversity, encouraging the availability of information that can promote geological heritage conservation initiatives.
Gaibu mud bath (Santo Agostinho Cape, Pernambuco, NE Brazil): geological heritage and healthy lifestyles	Guimarães, TO, et al.	2015	Contribute to sustainable development and geotourism in the region.

Geotourism potential en the coastal zone sur from the state of Pernambuco (NE Brazil)	Guimarães, et al.	2015	It highlights the main places of geological interest in this territory and their importance for the development of geotourism in the region. This reality will allow the development of geoconservation initiatives and promotion of geodiversity, contributing to the integrity of the environment, social justice and economic development of the territory
Serra da Santa: landscape, cartography and heritage	Santos, K.P.	2015	No access. – Justification : Course Completion Work not available by the University.
geotourism development in the municipality of Lagoa dos Gatos- PE	France, LFO	2015	An inventory of geosites was carried out considering the thematic and systematic inventory proposed by Sharples (2002) based on the classification approach based on the geological-geomorphological context of the region.
Geodynamic processes and landscape modification: Pedra Furada Park (Venturosa – Pernambuco)	Arruda, IRP, Guimarães, TO	2015	Highlight the importance of “Pedra Furada”, a geomorphological feature resulting from the association of different natural processes, as well as encouraging its conservation of this geological and geomorphological heritage.
Geotourism as a basis for the tourist development of Lagoa dos Gatos/PE	Silva, TRF, et al.	2016	No access. – Justification : Ebook website under maintenance.
Geodiversity and Biodiversity in the southern coastal zone of Pernambuco: a case study of Praia de Maracaípe , Ipojuca/PE	Lima, GR, et al.	2016	highlight the relevance of “Praia de Maracaípe ” due to its great importance of fauna and flora dependent on the mangrove ecosystem, in addition to its coastal geomorphology that results from the association of different natural and anthropic processes, as well as proposing the geoconservation of its geodiversity elements and geotourism as a sustainable development activity.
Beachrocks of southern coastal zone of the state of Pernambuco (Northeastern Brazil): geological resistance with history .	Guimarães, TO, Et Al.	2016	Show that the heritage significance of beachrocks in the southern portion of the coast of the State of Pernambuco exceeds their geological importance by associating scientific information with leisure tourism, aiming to promote awareness for the conservation and appreciation of beach rocks in the study area as an important geological heritage and historical.
Geological heritage and geoconservation strategies: popularization of geosciences and sustainable territorial development for the southern coast of Pernambuco (Brazil)	Guimarães, TO	2016	The identification of the main elements of geodiversity, followed by the inventory of the geological heritage, based on its values and specificities.
Ipojuca volcanic neck : an attraction of scientific, tourist and cultural interest	Arruda, IRP, Guimarães, TO	2016	It is to inform the general public (students and tourists) who frequent the region of information that is easy to absorb and understand about geological processes, which originated during the final fragmentation of the Gondwana Palecontinent . Attention is also paid to promoting the territory through the practice of geotourism and geoconservation of its elements.
Geodiversity in Pernambuco: the peculiarities of the southern coastal zone: Praia de Maracaípe	Lima, RG, et al.	2016	And it is worth highlighting the relevance of “Praia de Maracaípe ” due to its great biodiversity dependent on the mangrove ecosystem, its coastal geomorphology and proposing the geoconservation of its geodiversity elements and geotourism as a sustainable development activity.
Ipojuca volcanic neck : an attraction of geotouristic interest	Silva, WSA, et al.	2016	Describe the geological processes of this volcanic body (rhyolite), in addition to the promotion of the territory through the practice of geotourism and geoconservation.
Landscape evolution: a case study of Pedra Furada Park - Pernambuco	Oliveira, RA, et al.	2016	Highlight the importance of the Park, due to its geomorphological characteristics and the action of surface processes, in order to encourage the geoconservation of this heritage.

Quantitative assessment of geodiversity sites using the cluster analysis technique: case study	França, LFO, et al.	2016	We sought to carry out a detailed study on the representative elements of geodiversity in the Municipality of Lagoa dos Gatos, in the State of Pernambuco.
Geotouristic itineraries on the south coast of Pernambuco: geodiversity, biodiversity, history, culture, sun and beach	Guimarães, TO, et al.	2016	The mapping of seven geotouristic trails of an interdisciplinary nature, in the area that comprises part of the Armando de Holanda Cavalcanti Metropolitan Park, more precisely on the Cape Promontory, in the municipality of Cabo de Santo Agostinho.
Biodiversity and Geodiversity in Serra dos Cavalos/PE	Assis, KSG, et al.	2017	Spatial analysis of Biodiversity and Geodiversity in Serra dos Cavalos in the State of Pernambuco.
Games - geoeducational - as a subsidy for geoconservation on the south coast of Pernambuco (NE Brazil): a proposal	Guimarães, TO, et al.	2017	It highlights the relevance of the educational process based on activities aimed at formal and non-formal education. The importance of using specific materials aimed at geodiversity and geological heritage is confirmed.
Geotourism: proposal for territorial valorization and sustainability as an alternative to “sun and beach” tourism on the south coast of Pernambuco – Brazil.	Guimarães, TO, et al.	2017	It highlights the main physical and social characteristics of the southern coast of Pernambuco, presents a brief analysis of current tourist activity in the region and presents a proposal to enhance existing tourism, this now based on the pillars of natural heritage, geoconservation and sustainable territorial development.
Geodiversity in Venturosa: a case study in Parque da Pedra Furada – Pernambuco	Arruda, IRP, et al.	2017	Highlight the importance of the Park due to its geomorphological, geological characteristics and the action of surface processes, in order to encourage the geoconservation of this heritage through geotourism.
Qualitative and quantitative assessment of geodiversity sites in the municipality of Petrolina-PE	Barros, RGL, et al.	2017	Carry out a qualitative and quantitative assessment of geodiversity sites, in order to assess the vulnerability and conservation status of geodiversity in the municipality of Petrolina-PE.
Geodiversity of the internal continental shelf of Recife/PE, Brazil, and its influence on the distribution of marine habitats	Oliveira, T.S.	2017	Mapping the geodiversity of Recife's internal continental shelf, based on abiotic data, in order to infer potential benthic marine habitats.
Geotechnologies applied to geodiversity studies in the municipality of Petrolina-PE	Barros, RGL; France, LFO	2017	Develop a procedure that allows adaptation, simplification and precision in field work on geodiversity in the semi-arid region, as well as providing a cartographic record of possible geodiversity sites in the municipality of Petrolina through geoprocessing.
The inselbergs importance in the caatinga for the birds of prey conservation in Petrolina	Martins, FC, et al.	2017	Verify the occurrence of species of birds of prey in inselberg areas in the Petrolina Caatinga.
Inventory and diagnosis of geodiversity in the municipality of Petrolina	França, LFO, et al.	2017	No access. – <i>Justification</i> : Symposium Proceedings website under maintenance.
Geodiversity on Maracaípe beach : a study of	Bishop, CO, Et Al.	2017	Highlight the relevance of “Praia de Maracaípe ” due to its great Biodiversity dependent on the mangrove ecosystem, its coastal

case on the south coast of Pernambuco			geomorphology and propose the geoconservation of its Geodiversity elements and geotourism as a sustainable development activity.
Dissemination of geology teaching based on the interpretation of geological concepts and the paleontological heritage of the Araripe Basin	Penha, FAS	2017	Bring the experience of a Geology and Paleontology study group (High School Geology and Paleontology Study Group – GEOMÉDIO) with twenty first-year high school students at the Dom Helder Câmara Reference School, located in the municipality of Lagoa Grande, State of Pernambuco.
Analysis and interpretation of geodiversity and biodiversity of the landscape in Serra dos Cavalos/Pernambuco	Lima, GR, et al.	2017	Identify and analyze the landscape in Serra dos Cavalos, with the aim of understanding Geodiversity and local Biodiversity dependent on the Atlantic Forest ecosystem.
Qualitative and quantitative assessment of geodiversity sites in the municipality of Petrolina-PE	Santos, A.M.	2017	Inventory and quantify geodiversity sites in the municipality of Petrolina.
Inventory and qualitative assessment as a support for geoconservation and geotourism: southern coast of the state of Pernambuco (Northeast-Brazil)	Guimarães , TO, et al.	2017	The work comprises a case study, where 13 geosites were selected, using a qualitative approach methodology, with the initial objective being the description, classification and valuation of this geological heritage, resulting in an inventory of the geological heritage of this region.
The production of geoeducational resources for teaching geology in basic education	Silva, A.I.S.	2017	No access. – <i>Justification</i> : The production page is undergoing maintenance.
Inventory and diagnosis of Geodiversity in the municipality of Petrolina-PE	France, LFO, et al.	2017	No access. – <i>Justification</i> : Symposium Proceedings website under maintenance.
Geoconservation and local development strategies at the Serrote do Urubu geomorphological site Petrolina-PE	Fernandes, E. M.	2017	No access. – <i>Justification</i> : Symposium Proceedings website under maintenance.
Inventory of the pedagogical potential of geodiversity sites in the municipality of Petrolina-PE	Sousa, ME, et al.	2018	It deals with the geodiversity of the municipality of Petrolina-PE, located in the Brazilian semi-arid region.
Environmental impacts of ecotourism in Catimbau National Park-PE	Silva, DC, et al.	2019	Gather technical information that made it possible to qualitatively verify the environmental aspects and their respective impacts on the Catimbau National Park linked to ecological tourism.
geotouristic potential of the Serra do Areal geomorphological site - Petrolina-PE	Silva, E.R.D.	2020	No access. – <i>Justification</i> : Course Completion Work not available by the University.
Landscapes of the municipality of Petrolina/PE: paths for geotourism and geoeducation in the	Guimarães, TO, et al.	2020	Raise awareness among society and public authorities about the possibility of enjoying local landscapes and being able to develop strategies to guarantee, through scientific research and encouraging geotourism, an increase in the economy and geoconservation of these environments.

Submédio São Francisco Valley			
Assessment of the potential Açude das Pedras geosite in the municipality of Petrolina - PE	Santos, R.C.	2020	No access. – Justification : Course Completion Work not available by the University.
Geotouristic potential of the river islands of the Sub-middle São Francisco	Gama, E. S et al.	2021	We sought to identify the scientific and educational values and their geotouristic potential in the sub-middle of São Francisco
Geodiversity, geoheritage and society	Guimarães, TO	2021	Present the concept of geodiversity, geoheritage and forms of appreciation and rational use of these abiotic elements, especially in non-formal teaching spaces, from the perspective of geoeducation , geotourism and local economic development.
Arrecifes, Recife's seaside promenade. important Holocene record of relative sea level above current	Barreto, AMF; et al.	2021	A preliminary attempt at preservation is intended to publicize and illustrate this natural heritage through interpretive panels showing its origin, evolution and historical importance, as we consider the beach rocks of Pina and Boa Viagem, aged $7,310 \pm 60$ years BP and $5,805 \pm 40$ years AP
Stone heritage in Cabo de Santo Agostinho (PE): from the final stages of opening the Atlantic to the present day	Guimarães , TO, et al.	2021	Highlight the relevance of stone materials and their geological, historical and cultural importance in the region of the municipality of Cabo de Santo Agostinho, south coast of Pernambuco, Northeast Brazil.
L imitations and possibilities for geotourism on Fogo Island, between the cities of Petrolina - PE and Juazeiro-BA	Santos, M.B.	2021	No access. – Justification : Course Completion Work not available by the University.
Geomorphological inventory of the occurrence of lunchboxes in the district of Fazenda Nova, municipality of Brejo da Madre de Deus, rural Pernambuco	Lima, G.R.	2022	Interpret the geomorphological meaning of lunchboxes in the context of the semi-arid countryside of Pernambuco, seeking to establish parameters and geoconservation strategies for these forms, through carrying out an inventory, which requires policies and management instruments at the local level.
Geoconservation proposal in the district of Fazenda Nova - Brejo da Madre de Deus - Pernambuco, NE Brazil	Arruda, IRP, Et Al.	2022	Highlight the scientific and social importance of these geomorphological features resulting from the association of different natural processes, as well as encouraging geoconservation and geotourism of this geoheritage in the district of Fazenda Nova, Brejo da Madre de Deus – PE.
Geoeducation on the edges of the municipalities of Juazeiro/BA and Petrolina/PE	Guimarães, TO	2022	Preparation of a field itinerary between the riverbanks of the municipalities of Juazeiro/BA and Petrolina/PE, with stops at 4 main points, for observation and interpretation of the landscape.
Geodiversity: theory and geoeeducational practices on the edges of the municipalities of Juazeiro/BA and Petrolina/PE	Gama, ES	2022	No access. – Justification : Course Completion Work not available by the University.

Geodiversity index of the municipality of Paulista – Pernambuco (Brazil)	Arruda, IRP, et al.	2022	Apply a Geodiversity Index to the territory of Paulista/PE, in an attempt to promote knowledge, associated with the dissemination of this type of mapping as a tool to support regional geodiversity studies.
Geoeducational games : teaching and learning tools for Elementary School II students	Silvano, D.F.	2022	No access. – Justification : Course Completion Work not available by the University.
Challenges of educational tourism in the Vale do Catimbau National Park (PE)	Rocha, MH M; Oliveira, NSM	2022	Identify the challenges faced by teachers and tour guides for the development of pedagogical tourism in the Vale do Catimbau National Park, located in the state of Pernambuco.
Geoeducational itinerary to support Geography teachers in field classes: Serra da Santa and Pedra da E Escritoda Petrolina/PE	Rodrigues, L.F.	2022	No access. – Justification : Course Completion Work not available by the University.
Inventory of scientific potential in weathering pits in the district of Fazenda Nova - Pernambuco, Northeast of Brazil	Lima, GR, et al.	2022	Through inventory, find answers to many questions that explain the process of articulation between erosion, sedimentation, weathering, fossilized materials, among other attributes corresponding to dissolution lunchboxes.
Geoeducational proposal for the Rajada geosite - Petrolina/PE: strategies for basic education	Silva, P.R.	2022	No access. – Justification : Course Completion Work not available by the University.
Geoeducational route : environmental perception and geoconservation on the riverfront of Juazeiro/BA and Petrolina/ PE	Gama, ES; Guimarães, TO	2022	The elaboration of a geo-educational itinerary , aiming at the visitation and integrated analysis of the landscape, with an emphasis on geodiversity, highlighted by the presence of the São Francisco River, its dynamics and processes.
Geoconservation proposal in the Fazenda Nova district, Brejo da Madre de Deus, Pernambuco, NE Brazil	Arruda, IRP, et al.	2023	Value the tanks (Marmitas) in terms of scientific aspects resulting from physical, chemical and biological weathering, as well as encourage geoconservation and geotourism of this geoheritage in the district of Fazenda Nova, Brejo da Madre de Deus, in the state of Pernambuco.
Characterization of Pernambuco's geoheritage: Analysis of the geodiversity index of the North Coast – Northeast of Brazil	Arruda, IRP, et al.	2024	Apply a geodiversity index in the northern coastal zone of the state of Pernambuco using geotechnology, associated with fieldwork and bibliographical research, aiming to promote the territory and make information available in order to enable the inventory of geosites in the aforementioned area.
GEOPATRIMONY OF PERNAMBUCO: Website promoting the geodiversity of the state of Pernambuco	Arruda, IRP, et al.	2024	Provide society with information about Pernambuco's Geoheritage with means of dissemination, focused on the biotic and abiotic elements of the state, through published and ongoing work, professionals involved, routes, itineraries and maps.

Source: Authors (2024)

It can be seen that, according to Table 01, the published works are based on the central theme, involving the discussion of Geodiversity, and that each one resorts to the specificities of the environment, adding contributions about geoconservation, geotourism, geoeducation and /or geocommunication, providing the dissemination of geosciences and the promotion of Pernambuco's geoheritage.

Some of the published works were not found in the available databases. Therefore, it was not possible to read the geodivulged material in full. The need and importance of taking this scientific knowledge to formal and non-formal

environments is highlighted. Since everyone needs to understand the need to conserve these elements for future generations. Therefore, the importance of materials like these being available to the community in general is reinforced.

In total, 76 works were found in the available databases that addressed the concept of geodiversity or related themes (geotourism, geoconservation, geoeeducation, geodidactics). From this survey, 07 works are doctoral theses: (1) for the entire state through the geodiversity index; (4) for the coast of Pernambuco; (2) for the rural region.

Six master's theses were also found, divided into: (3) for the coast of Pernambuco; (2) facing the countryside; and (1) facing the hinterland. According to the data search, 22 articles are available and 10 are book chapters. There is a five-year publication gap (2005-2010) and in 2019, only one published work. The years 2016 and 2017 were crucial in the development of research at master's and doctoral levels, which resulted in several articles published in national and international journals.

The University of Pernambuco, Petrolina campus, led the way with 10 course completion works (geography) between the years 2017 and 2022 covering concepts and themes, however, not all of them are yet available for reading. The other works are divided between abstracts (15) and expanded summaries (11) published in proceedings, conferences and symposia between the years 2011 and 2022. The year 2024 has only two articles published. The most cited authors, in numerical order, were: I-Guimarães, TO (31 works); II-Mariano, G. (22 works); III-Arruda, IRP (19 works); IV-França, LFO (12 works) and V-Lima, GR (10 works).

It is also noteworthy that the work developed by Guimarães (2016) earned an honorable mention for the Capes Theses Award in 2017, in addition to being the first in the country to have the Unesco Chair seal. The importance of works like this in popularizing abiotic elements in light of environmental dynamics, conservation proposals and territorial planning can be seen.

3.2. We point out Pernambuco Geoheritage

When analyzing the diversity and complexity of abiotic elements, it is important to take into account the magnitude of elements present in a given environment, associating them with different scales of analysis and contribution to geosciences. The global scale deals with the history of the Earth and plate tectonics, which are fundamental to understanding current geological diversity. In Pernambuco, we can attribute the formation of the South Coast to the existence of certain outcrops as markers of the evolutionary history of planet Earth (breakup of the megacontinent Gondwana), namely: the Cabo promontory, the volcanic *neck* of Ipojuca, Volcanic Island of Santo Aleixo and others (GUIMARÃES, 2016). On the North Coast we have Praia Ponta do funil – Barra de Catuama, in Goiana, which demarcates, through its stratigraphy belonging to the Paraíba Sedimentary Basin – Olinda Sub-Basin, the opening of the Atlantic Ocean (ARRUDA, et al., 2024b).

In a local scale analysis, it is important to attribute key elements, such as: materials, processes and landforms that make up the portion of geodiversity. These elements can be described according to intrinsic, scientific, historical, cultural, educational, aesthetic, tourist, economic and functional values (BRILHA, 2005). It is worth mentioning that the anthropic presence is mainly attributed to cultural value, since under these elements man develops social, political, economic, scientific, educational, leisure and other activities.

At the local scale, we can also take into account influence and economic power as key points for development and management. Environments such as Porto de Galinhas Beach, Muro Alto Beach, Muro Alto Beach Coroa do Avião Island, etc. – on the coast of Pernambuco, Serra das Russas, Caruaru-Arcoverde Batholith, Marmitas de Dissolution, Cachoeiras de Bonito, etc. – in the countryside of Pernambuco, and the river islands of São Francisco, Petrolina Paleodunas, Inselbergs and others – in the backlands of Pernambuco, form this local geodiversity and most of them are tourist attractions that often generate significant income for local residents. The elements mentioned above are part of the study areas presented in table 01.

The sum of these and other locations are merely important and highly valued in the representation of Geodiversity (BISPO, et al., 2017; GUIMARÃES, et al., 2021; LIMA, 2022). However, there are certain geoenvironments that have exceptionally considerable values, whether due to their genesis, form, peculiarity, history, culture and others that need to be conserved and/or preserved for future generations. In the literature, the sum of these values allows us to classify geosites.

In Pernambuco, there are several points inventoried and classified as Geosites. From north to south, from east to west you can find a catalog of suggested and accredited areas. It can be found on the CPRM website, through the website <<https://www.cprm.gov.br/geossit/geossitios>>. Among them, registered, the most significant in terms of published works are the Mina Poty Geosites K-Pg; Sandstones of Porto de Galinhas, Sandstones of Muro Alto, Rhyolite of Ipojuca, Serra das Russas, Açude das Pedras, Parque da Pedra Furada, Mirante do Chapadão; Mimoso Mylonite and others (Figures 01 and 02).

On the site, it is possible to identify the relevance of the geosite in Regional/Local Relevance; National Relevance; International Relevance and Unclassified (Figures 01 and 02). It is noteworthy that several other geosites were suggested by Guimarães (2016) and Santos (2016), included on the platform, but have not yet been accepted/made available.

Therefore, geosites contain data that can reveal expressions of the past through paleoenvironmental and climatic reconstruction, and also contain evidence of the evolution of a geoenvironment through sediments, stratigraphic units and the presence of fossils. And these elements can be linked to both local and global interests. For example, the Mina Poty Geosite , which has the anomalous presence of iridium that has been described at the site and in many other places around the world.

Thus, the sum of these elements constitutes what we know in classical literature as geological heritage. It is noteworthy that Geodiversity includes all elements of this heritage, be it geological, geomorphological, archaeological, paleontological and others.

In the literature, it is common to find multiple additions to the name heritage, either with geological and geomorphological aspects, the most cited, or with others. Depending on the type of geodiversity element of relevance, geological heritage can be subdivided into specific types, such as tectonic, geomorphological, sedimentological, hydrogeological , mineralogical, petrological , paleontological and others. However, contemporary researchers use the short form “geoheritage”, in an attempt to include all these elements of geodiversity, and to define new analytical biases for them added to classical methodologies and their adaptations.

However, contemporary researchers use the nomenclature “geoheritage”, in an attempt to include all these elements of geodiversity, and to define new analytical biases for them added to classical methodologies and their adaptations. In other words, the use of the term “geoheritage” becomes much more inclusive, as it brings together all physical aspects without adding “preference” to a single title, taking into account the specificities of the area analyzed. Different from authors who use “Geological Heritage” and add a weight value to a single element. When analyzing a work that uses the expression above, it is clear that not just one element was used, but several. Hence, there is a need to use and promote geoheritage terminology in future publications within geosciences.



Figure 01 – Location of geosites inventoried and made available on the Geossit – CPRM website.

Source: Geossit (2024).



Figure 02 – Examples of geosites inventoried according to their relevance. A- Geosite of international relevance; B- Geosite of national relevance and C- Geosite of regional/local relevance. Source: Geossit (2024).

For Arruda et al (2022), natural monuments are characterized by being geoheritage and need to be identified, investigated, inventoried and conservation proposals need to be developed and put into practice. For Gama and Guimarães (2022), with the purpose of encompassing geodiversity and geoheritage, the term geoheritage emerged with the aim of expanding the approach of researchers from other areas of geosciences, without restricting it only to geological science. Therefore, it is clear that the state of Pernambuco is a region with multiple physical characteristics and that if we could observe each region in detail we would see the magnitude and the need to sustainably explore the various geoheritages that are present here.

It is worth highlighting that new considerations involving the concept of geological heritage, geosites and geodiversity itself were worked on and discussed by Brilha (2016). Geodiversity can be analyzed through the attribution of values, which are: (i) scientific and (ii) other values, linked to what we know as *in situ* and *ex situ* (FRANÇA, et al., 2016).

With regard to the category of analysis of environments classified as heritage, it is important to understand that when elements (physical/natural sites – rocks, relief, water, sediments) are analyzed, understood, catalogued, measured, inventoried and conserved, they are classified into *in situ*. However, when these testimonies are removed from their place of origin and taken to specific centers (museums, study centers, research) they are called *ex situ* heritage.

This work adopts the nomenclature of Geoheritage, since for geodiversity the inclusion is of all elements and not just geology, for example, as specified by the nomenclature of Geological Heritage. We can observe that works of great relevance to the state, at national and international level, use/adopt the same definition.

Through the applicability of a Geodiversity Index, Ferreira (2014), provided the identification and characterization of Pernambuco's Geodiversity, in an attempt to encourage and make available information that can promote heritage conservation initiatives, whether geological, geomorphological, pedological, hydrographic, hydrogeological, paleontological, archaeological and others. Through this research, it was possible to measure the geological and geomorphological richness of the state. As well as, identify possible areas of geodiversity interest that need to be analyzed in the eyes of conservation and sustainable tourism.

Still according to the work mentioned above, the entire coast of Pernambuco, for example, can be seen as a great geoheritage. Because, it has key elements of geodiversity that tell the evolutionary story of the Earth, at an international level; provides tourism development in the region, at a regional level; allows the inclusion of conservation strategies in addition to territorial orders and planning, at the local level. And they all directly impact the social, economic, historical and cultural conditions of the place.

The South Coast was the scene of many discussions and there is already a proposal to make this region a Geopark in accordance with UNESCO regulations and guidelines. There is also work being developed on the North Coast adopting the same methodologies and with the same purpose. Like Guimarães (2016) who inventoried 13 geosites (all registered in Geossit) on the South Coast of Pernambuco and worked on them beyond the scientific and tourist point of view, in a geoeducational way, developing games with the theme of the inventoried geosites, in However, none of them appear on the platform. Santos in 2016, also inventoried 12 geosites and all of them were registered in Geossit. However, none of them have yet been made available on the website. The importance of management by CPRM in an attempt to resolve these operational conflicts is highlighted and that the inventoried materials can be published and made available to the scientific community and other interested parties.

It can be seen (Figure 02) that there are still spaces in the state of Pernambuco with gaps involving the guiding discussion. There are municipalities that have cataloged geosites, but do not have published research and/or geotourism strategies. And areas with published work, but which have not yet been registered in CPRM Geossit as geosites.

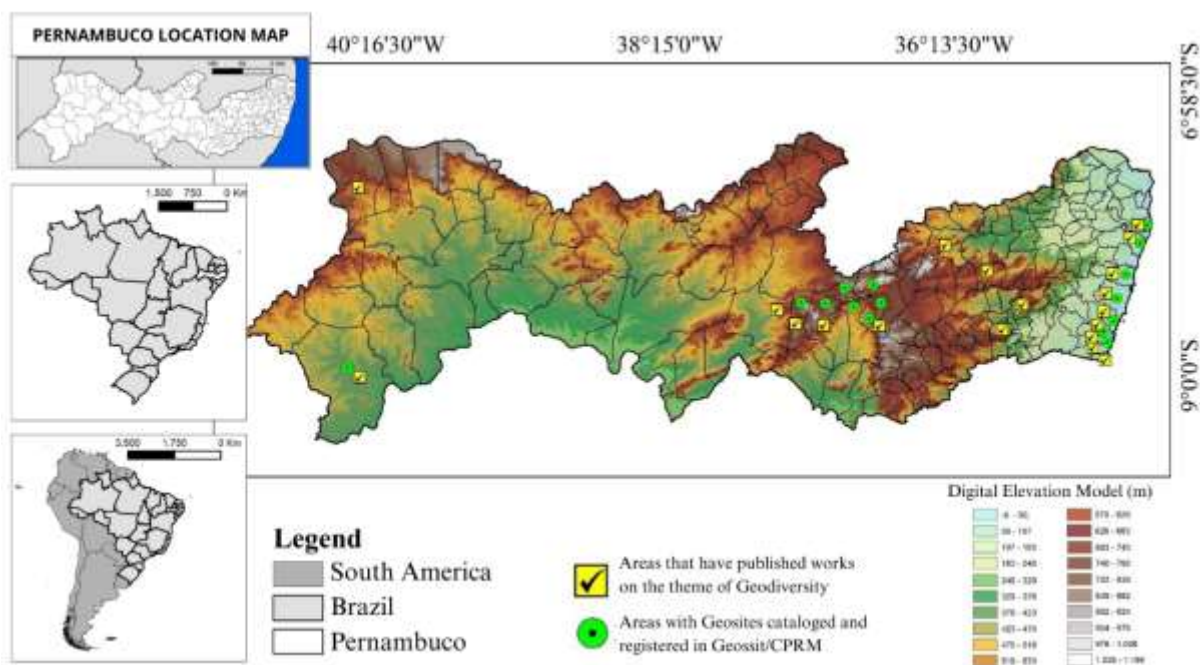


Figure 02 – Location of areas with discussion on Geodiversity in the state of Pernambuco - Northeast of Brazil.
Source: Authors (2023)

3.3. Geoconservation, geotourism and geoeeducation in the regional context

Based on the concept of Geodiversity, many proposals involving geoconservation, geotourism and geoeeducation were raised for the state of Pernambuco. According to table 01, the works promote discussions involving other perspectives of analysis and conservation of these elements. Added to the initial concept, we have Geoconservation which aims to propose effective measures to conserve/preserve any abiotic elements, guaranteeing their use in future generations.

For Brilha (2005; 2016), geoconservation allows the development and use of practices and/or strategies that allow the conservation of geological elements that have undeniable scientific, cultural, tourist and other values. With the aim of conserving areas of relevant geological and geomorphological interest, geoconservation emerges, equipped with tools aimed at the conservation and dissemination of natural elements (GUIMARÃES, 2013)

Years later, Guimarães (2016), reiterates his argument that when talking about geoconservation, the concepts of geological heritage and geodiversity must be well defined. You need to know what and how to preserve, conserve and use. Well-accepted and diluted practices in the cataloging of Pernambuco geosites and in the creation of state parks, namely: Parque do Catimbau, Parque da Pedra Furada and others. It is known that:

The development of an appropriate geoconservation strategy must take into account factors such as the relevance of the geological and geomorphological information found in the area to be protected and also the degree of vulnerability to impacts resulting from human action to which it is exposed, in order to create mechanisms that facilitate people's approach and also protect areas of geological interest (SANTOS, 2012, p. 78).

Still according to Santos (2012), despite the elements of geodiversity boosting tourism in the municipality of Bonito/PE, for example, the geological focus is not yet present in this segment, which contributes to greater vulnerability in some of its areas in consequence of human activities, which are quite active.

For Mariano *et al.* (2013), in the countryside of Pernambuco, we have the granite arch of Pedra Furada de Venturosa, which is a cataloged geosite, which has a rare geological-geomorphological feature in Brazil. According to authors, for the locality, the applicability of geotourism in the location allows the development of an understanding of the morphology

observed from a scientific point of view and the tourist stops being a mere observer to find out how that particular feature was formed and how it can be preserved/conserved. We know the importance of including the local community as protagonists of conscious actions.

Still in the countryside, we have the work developed by Arruda (2013) in the municipality of Araripina, located in the west of the state of Pernambuco, characterized by its Geodiversity, under mineralogical, paleontological and Geomorphological aspects. The final result was a Geodiversity map that provided a visualization of the areas of greatest interest for geoconservation and geotourism. The author also suggested several purposes (political, social, educational, economic) with the use of the geodiversity index.

Another very pertinent work developed in the countryside was that of França (2015), in the municipality of Lagoa dos Gatos, located in the Agreste mesoregion and which is inserted in the Brejo Pernambucano microregion. The study focused on contemplating a rich scenario, involving geodiversity and local biodiversity, consisting mainly of waterfalls, granite geofoms , mountains, extensive flagstones and an Atlantic forest reserve. The research inventories some geosites considering the thematic and systematic inventory proposed by Sharples (2002) based on the classification approach based on the geological-geomorphological context of the region. The author also suggests that the use of geotourism has been a powerful tool for the dissemination, appreciation and conservation of geodiversity.

Geotourism is part of the tourist activities whose objective and need is to promote the dissemination and knowledge of geoheritage, people who wish to travel with the intention of knowing and learning more about geoenvironments (FRANÇA *et al.*, 2013a, 2013b). As it is most often practiced in natural areas, geotourism can be an important tool for developing actions to preserve natural heritage (FRANÇA, *et al.*, 2011; SILVA JUNIOR, 2013; GUIMARÃES, *et al.*, 2015).

Geotourism is a segment that has been growing every year, being a new trend in terms of tourism in natural areas (MOREIRA, 2014; ARRUDA, *et al.*, 2023). For Manosso *et al* (2014), it is very important to combine ecotourism, tourism and geotourism in conservation units and the tourist attractiveness promoted by the set of geodiversity elements, and sometimes related to geological heritage, is a primary factor for development as a whole, as both end up being more significant as a focus of tourist attraction and motivation in the place. In places where tourism already occurs, the development of geoconservation and geotourism becomes essential.

According to Guimarães *et al* (2016; 2017b) it is necessary to create a geotouristic itinerary in a multidisciplinary way, as we have Geodiversity as the main focus, but at the same time, it encompasses as many interests as possible in a given territory, valuing and respecting local cultures and the communities involved.

In the work developed by Guimarães (2013), some proposals were presented aimed at disseminating local Geodiversity and improving infrastructure in the Armando de Holanda Cavalcanti Metropolitan Park, located in the municipality of Cabo de Santo Agostinho/PE, in order to highlight dissemination and conservation of the geological, geomorphological, environmental and historical elements of the area, as well as its geotouristic potential . The park surrounds the area where the Cabo de Santo Agostinho granite and the volcanic rocks that cut through it occur. These rocks have ages dated to ca 102 ma ., which mark one of the final stages of the breakup of the Gondwana megacontinent , knowledge of global relevance.

Within Geosciences there is the possibility of association, work and performance of the association of key elements of geodiversity, geoheritage, geoconservation and geotourism. To this end, diagnosis through data collection, selection and evaluation of outcropping sites of geological, geomorphological, archaeological and paleontological testimonies) is of utmost importance, through conservation that aims to evaluate legal aspects, monitoring, quantification and inventory, and promotion through the valorization of these geoenvironments and scientific dissemination/promotion.

When thinking about Geodiversity for areas with great geological and geomorphological values, for example, regardless of scientific purposes, it is necessary to include geoconservation And when possible and linked to the social and historical context, it is important to develop geotourism that can combine conscious use with sustainable purposes. Therefore, the misuse of physical elements can be irrational and/or irreversible.

Thus, in addition to scientific use, for inventory purposes, geoheritage when identified, analyzed and managed will have effective geoconservation methods and applicability. The possibility, for example, of geotourism, which allows visits to these cataloged locations, which often have significant scenic beauty in social eyes, adding to the dissemination of scientific knowledge of this geoenvironment in a different and targeted way. In the reality of the South Coast of Pernambuco, on internationally known beaches, for example: such as Muro Alto, natural pools of Porto de Galinhas, Maracaípe and Tamandaré, developed tourism is only sun and beach, and the historical context, unfortunately, is devalued. This is a reflection of public management and planning policies that are often non-existent and/or ineffective.

Many of the challenges faced by academia are extending what is developed in science to the population. Therefore, through geoeeducation , it is possible to use didactics as a guiding key to knowledge and, through multiple tools, enable

scientific learning in formal and non-formal environments. Cultural value is what matters most depending on the criteria and audience to be worked on, as local identity and recognition are quite strong. As a way of expressing this idea, the possibility arises of developing folders, booklets, educational games, virtual trails, suggestive maps and others, using geodiversity elements adding fun and scientific knowledge.

For Guimarães *et al* (2017), in any territory, where there is geodiversity and relevant geological heritage, as well as communities living and promoting their activities, it is possible to promote an interdisciplinary tourist activity, of sustainable territorial development, which adds value to the pre-existing activity of integrative, participatory way and guided by the principles of geotourism. To this end, interaction between geosciences, academia, researchers, the community and the promotion of knowledge is of utmost importance.

It is worth remembering that the discussion regarding Geoheritage inventory, Geoconservation strategies, Geoparks, Geotourism and dissemination of Geosciences must take place directly in formal and non-formal teaching spaces, through the preparation and application of geoeducational materials, for example. Therefore, the importance of the link between academia, government, society, formal and non-formal spaces is highlighted.

4. Final considerations

Even though it is a branch of research in Geosciences, consolidated by Sharples (2002), Reynard (2005), Brilha (2016), Gray (2019), among others that are disseminated in world literature, expanding in Brazil, studies on the themes focused on the abiotic environment “Geodiversity/Geoconservation/Geotourism/ Geoeducation ” in the state of Pernambuco, assume fundamental importance in promoting the maintenance and sustainable use of these areas of geological, geomorphological interest and other abiotic aspects.

Thus, it is understood that through interdisciplinarity and popularization of science it is possible to raise awareness among the population about the importance of geoheritage and conversation strategies linked to tourism and environmental practices. The state has several areas within the greater Province of Borborema and adjacent areas that need to be explored, cataloged and deserve attention from the perspective of geodiversity and geoconservation.

It can be seen that the coast of Pernambuco is home to many academic works, followed by the hinterland, and finally the countryside. The region with no published work involving the topic under discussion was the forest zone. This is often due to the absence of public policies that encourage the development of this research. Therefore, it is important to look at the public and private spheres in an attempt to promote Pernambuco’s geoheritage. The need and importance of taking this scientific knowledge to formal and non-formal environments is clear. Since everyone needs to understand the need to conserve these elements for future generations.

It is worth highlighting the need for more research in different parts of the state of PE, since it is possible to catalog several places as true geoheritage. In literature and in the rapid growth of geotechnologies, many methodologies have been developed, such as educational trails, three-dimensional mapping, drone applicability , satellite images, use of QR *codes* and others, to directly impact the results of research involving geodiversity. It is important to invest in their applicability to further propagate the discussion and generate unprecedented results that change the reality of people and spaces and that these are preserved for future generations.

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