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# GEODIVERSITY AND GEOTOURISM IN SERIDÓ POTIGUAR, NE BRAZIL

# GEODIVERSIDADE E GEOTURISMO NO SERIDÓ POTIGUAR, NE DO BRASIL

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**RESUMO**
No Estado do Rio Grande do Norte, as microrregiões do Seridó Oriental e da Serra de Santana expõem áreas com diversos registros de uma evolução geológica longa e complexa, que acabaram compondo o Seridó Geoparque Mundial da UNESCO. Diante dessa realidade, o objetivo desse trabalho é apresentar as diferentes perspectivas a respeito dos conceitos de geodiversidade e geoturismo, e a importância da preservação dos elementos abióticos da paisagem para o desenvolvimento do geoturismo, no semiárido potiguar.
**Palavra-chaves**: Geodiversidade; Seridó Potiguar; Geoparque

**ABSTRACT**
In the State of Rio Grande do Norte, the Seridó Oriental and Serra de Santana microregions have areas with important records of a long and complex geological evolution, which represent the UNESCO Seridó World Geopark. Therefore, the objective of this work is to present different perspectives on the concepts of geodiversity and geotourism, and the importance of preserving the abiotic elements of the landscape for the development of geotourism in the semi-arid region of Rio Grande do Norte.
**Keywords:** Geodiversity; Seridó Potiguar; Geopark

## INTRODUCTION

Efforts focused on environmental protection and sustainability are relatively recent compared to the history of sciences, with their beginnings linked to the growth of environmentalist movements from the second half of the 20th century. However, the preservation of biodiversity has always been the primary target of actions; it was only

from the 1990s onwards that studies and measures in favor of geoconservation began to be taken, mainly in European countries. In Brazil, studies began to be developed only in the 2000s (MEIRA; MORAIS, 2016).

The term geodiversity, a contraction of "geological and geomorphological diversity" (GRAY, 2008), emerged in the 1990s as an analogy to the term biodiversity, defined as "biological diversity," that is, as a manifesto describing the diversity of abiotic nature, emphasizing the importance of abiotic components and processes in environmental conservation (BORBA; SELL, 2018).



Stanley (2000) defines geodiversity as the variety of geological environments, phenomena, and active processes that give rise to landscapes, rocks, minerals, fossils, soils, and other surface deposits that support life on Earth. This definition was adopted by the Royal Society for Nature Conservation in the United Kingdom as the title of its informative Earth Science report (Geodiversity Update) (NASCIMENTO; MANSUR; MOREIRA, 2015).

Currently, one of the most used concepts is proposed by Gray (2013), who defines geodiversity as the "natural variety of geological elements (rocks, minerals, fossils), geomorphological features (landforms, topography, physical processes), soil, and hydrological elements." Some authors, such as Carcavilla, Durán, and Lopez-Martínes (2008), consider the definition of geodiversity more narrowly. For these authors, geodiversity is understood as the geological diversity of a territory, that is, the variety of geological features present in a specific area, with geomorphology being an integral part of these elements.

For Meira and Morais (2016), the main objectives in the study of geopatrimony are the popularization of concepts related to Earth Sciences, the protection of exceptional features of geodiversity, and the creation of a comprehensive environmental awareness that conceives nature as a dialectic between abiotic and biotic elements of the landscape. These purposes result in geoconservation, which according to Cumbe (2007, p. 43) consists of "activities aimed at the conservation and management of geological heritage and the natural processes associated with it."

It is with the intention of protecting this geodiversity that various actions have been implemented globally, especially from the 1990s onwards when geological communities worldwide began to be concerned about the disappearance of heritage elements of geodiversity, due to their irrecoverable nature after deterioration (MEDEIROS; OLIVEIRA, 2011).

In this perspective, it was in the year 2000, with the establishment of the European Geoparks Network, that one of the greatest actions in favor of geoconservation was consolidated. Subsequently, in 2004, another initiative in the realm of geoconservation emerged with the creation of the Global Network of Geoparks (Global Network of National Geoparks – GNN), comprised of a group of countries aiming to promote the conservation of a healthy environment, encourage education in Geosciences, and foster sustainable local economic development (BRILHA, 2005).

European geoparks gained visibility through their dynamism, by constituting a strategy for the valorization of economically depressed areas, by interconnecting natural and cultural aspects, and by encouraging Geotourism (MEIRA; MORAIS, 2016). In Brazil, initiatives for geoconservation of geopatrimony had their initial milestone in 1997, with the creation of the Brazilian Commission of Geological and Paleobiological Sites (SIGEP), with the purpose of cataloging Brazilian geosites for the global indicative list of geological sites (GILGES – Global Indicative List of Geological Sites) (CPRM, 2006).



Consequently, in 2006, the Geoparks Project was created by the Geological Survey of Brazil (SGB/CPRM), aiming to identify, survey, describe, diagnose, and promote areas with potential to be listed as future geoparks in the national territory, as well as to promote the inventory and quantification of geosites (CARVALHO, 2023).

According to Henriques et al. (2011), geosites are places on the Earth's surface that best represent certain processes, events, periods, and significant characteristics of Earth's identity, recognizable by the principle of singularity, for example, due to bearing a particular property recognized and valued by geoscientists, making it unique and, therefore, relevant for understanding the Earth's evolutionary history.

Faced with the need for conservation of geopatrimony and, at the same time, for it to be explored consciously, geotourism emerges, filling a gap in ecotourism, focusing on the visitation of natural areas where the main attractions are associated with geopatrimony, seeking to protect this heritage through public awareness (NASCIMENTO et al., 2008).

According to Moura-Fé (2015), geotourism presents itself as a promising segment of tourism activity, related to ecotourism, with specific characteristics essential for the conservation of geodiversity, in line with various precepts required for the local economic development of the communities that can and should be involved.

In light of the above, the aim of this work is to present geotourism as a tool for dissemination, recognition, and valorization of the geosites that make up the Seridó UNESCO Global Geopark, located in the state of Rio Grande do Norte, Brazil

## STUDY AREA: GENERAL ASPECTS

In the state of Rio Grande do Norte (RN), the microregions of Seridó Oriental and Serra de Santana expose areas with diverse records of a long and complex geological evolution, which, in evolutionary terms, have been associated with the Brasiliano Orogeny in the Neoproterozoic (BRITO NEVES et al., 2000); the fragmentation of the Gondwana supercontinent in the Cretaceous (MATOS, 2000); intracontinental rifting (CLAUDINO SALES; PEULVAST, 2007); marginal flexure of the transform continental margin (CLAUDINO SALES, 2016); and the Ceará-Mirim, Serra do Cuó, and Macau magmatism (ALMEIDA et al., 1988), in addition to morphogenetic processes observed throughout the Cenozoic (CORRÊA et al., 2010).

These two microregions of RN present sectors of the geographic territory, referred to as "sites of geological interest" (BORBA et al., 2016) or "geosites" (hotspots) (BRILHA,

2005; BÉTARD; PEULVAST, 2019), which ended up composing the Seridó UNESCO Global Geopark and best represent the geological evolution of the region, which, in terms of scale, can be punctual outcrops, sections, viewpoints, simple areas, or complex areas (FUERTES GUTIÉRREZ; FERNÁNDEZ MARTÍNEZ, 2010).

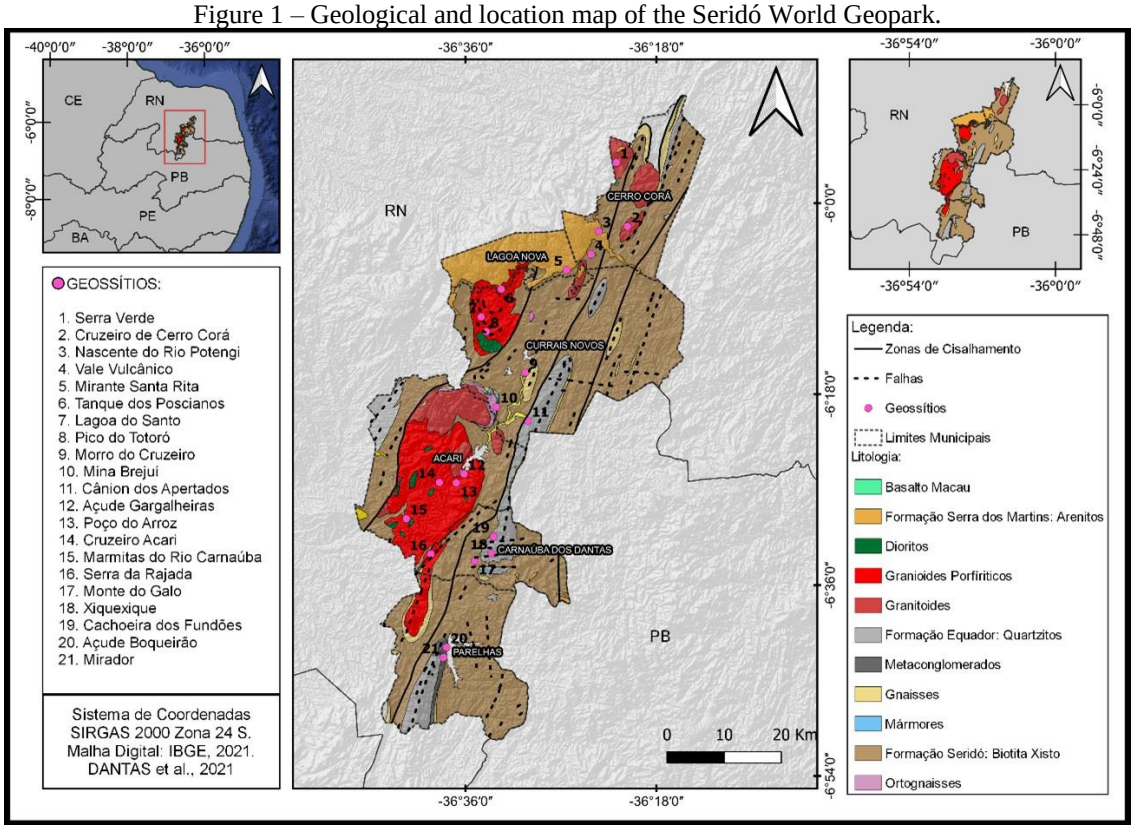
The geosites comprising the Seridó UNESCO Global Geopark reflect the richness of the geopatrimony of certain municipalities of the state of Rio Grande do Norte, such as Acari, Carnaúba dos Dantas, Cerro Corá, Currais Novos, Lagoa Nova, and Parelhas, which gather a set of abiotic elements of singular beauty, resulting from numerous natural processes associated with the evolutionary history of the Earth's surface, whose record can be observed in the various macro and micro landforms.



The geological history of the Seridó UNESCO Global Geopark began in the Rhyacian (~2.2 Ga), with orthoderived rocks of the Caicó Complex (e.g., orthogneisses). During this period, sediments were also deposited, composing the metasedimentary rocks dated from the Cryogenian (~640 Ma), associated with the Seridó Group (e.g., paragneisses, marbles, quartzites, micaxists). There are various types of igneous rocks (fine- to porphyritic-grained granites and subordinate diorites) dated from the Ediacaran Period (~590 to 530 Ma), as well as pegmatite dikes from ~520 Ma, basalt flows from ~25 Ma, and sandstones from ~20 Ma (SILVA; MANSUR; NASCIMENTO, 2022).

Therefore, the 21 geosites comprising the Seridó UNESCO Global Geopark reflect part of the geological history of the semi-arid region of Rio Grande do Norte, with lithological representatives of the main geological groups (e.g., Caicó Complex, Seridó Group) constituting the Precambrian crystalline basement of the state of Rio Grande do Norte (Figure 1).

Figure 1 – Geological and location map of the Seridó World Geopark.




Source: prepared by the authors (2023).



## MATERIALS AND METHODS

The methodological approach of this study was based on bibliographic surveys on geodiversity and geotourism, aiming to achieve a better understanding of the subject, as well as on the genesis and evolution of some of the geosites of the Seridó UNESCO Global Geopark. In addition, field trips facilitated a better recognition of the geosites and the processes associated with past and present morphodynamics. Drone overflights were also conducted during this stage to optimize the photographic collection and support a more detailed interpretation of the region.

The editing of the geological map of the Seridó UNESCO Global Geopark consisted of a correlation of cartographic revision, based on the geological maps of the state of Rio Grande do Norte, at a scale of 1:500,000 (DANTAS; MEDEIROS; CAVALCANTE, 2021), and the Borborema Pegmatite Province, at a scale of 1:250,000 (CABRAL NETO et al., 2018). Vector data were analyzed and edited using the QGIS 3.22.5 software, resulting in the production of the geological map and location map of the study area (Figure 1).

## RESULTS

Geomorphic Features of the Geosites in the Municipalities of Acari and Carnaúba dos Dantas: Exemplification and Potential for Geotourism Development

The Seridó UNESCO Global Geopark, with a total area of 2,802 km² and an estimated population of 110,000 inhabitants (SILVA; NASCIMENTO; COSTA, 2022), presents one of the most comprehensive and beautiful geopatrimonies found in the Brazilian Northeast.

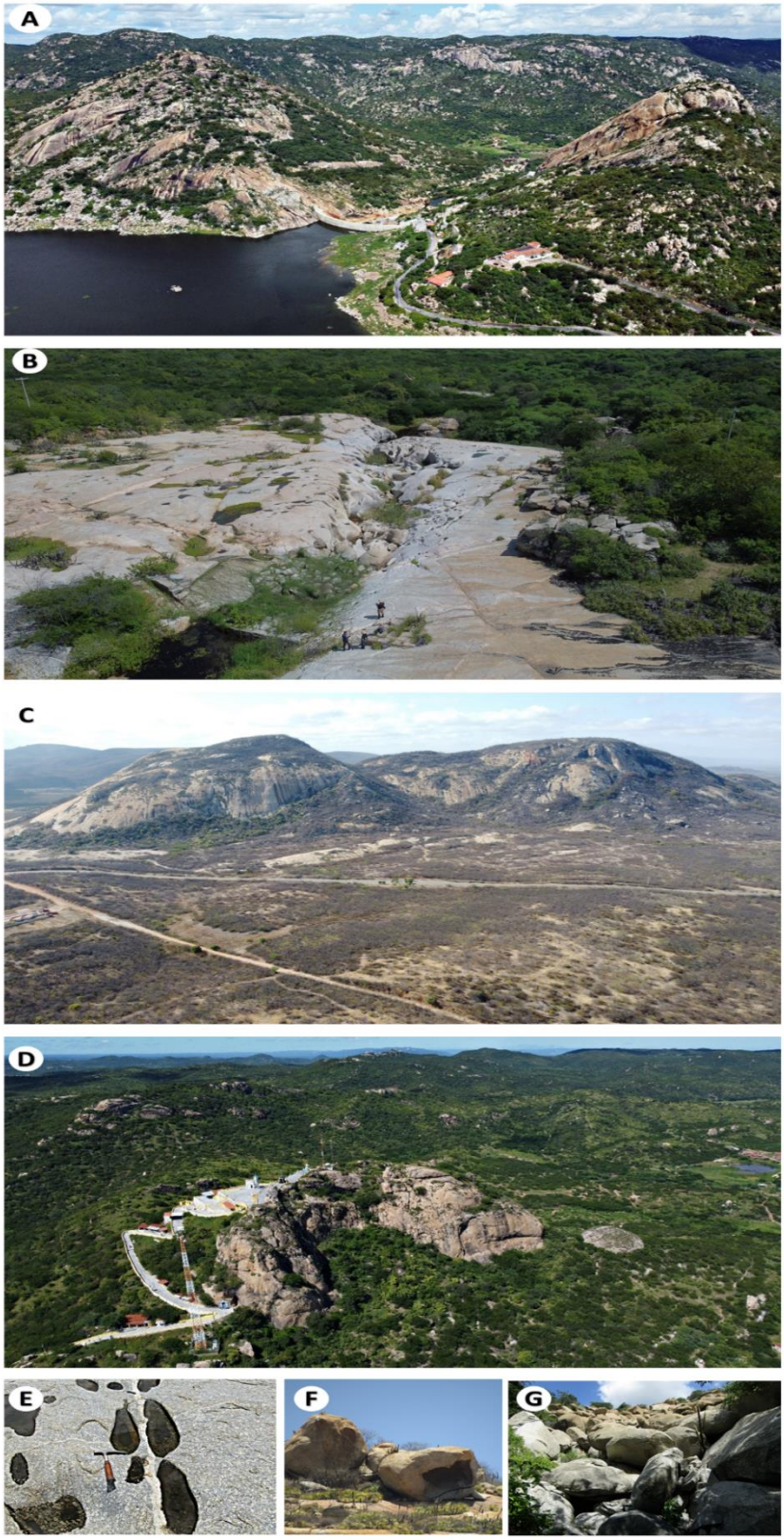
This geopatrimony is the result of numerous natural processes to which this region has been subjected over geological time. Given the exceptional nature of this geopatrimony, associated with the cultural aspect of the region, the area was recognized as a Global Geopark by the United Nations Educational, Scientific and Cultural Organization (UNESCO) on April 13, 2022, thus increasing the value of the geopatrimony in the Seridó Potiguar, as well as its landscapes, which are also key witnesses to the Earth's evolutionary history.



The exhumation of the Acari Pluton, located in the homonymous municipality, with an outcropping area of ~300 km² (CAMPOS, 2016), originating from the Brasiliano Orogeny (ANGELIM et al., 2003), which intruded the lithologies of the Seridó Group, such as the micaxists of the Seridó Formation (ANGELIM; TORRES; SANTOS, 2007), has revealed a diversified display of macro and micro-granitic landforms, such as massifs, inselbergs, inselgebirgs, bornhardts, boulders, tors, block chaos, rock pavements, potholes, rocky domes, and tafoni, whose origin and development are associated with weathering, both subsurface and surface, conditioned by mineralogical predisposition and the existence of ductile and brittle deformation planes.

The geosites Açude Gargalheiras, Cruzeiro de Acari, Poço do Arroz, and Marmitas do Rio Carnaúba, located in the municipality of Acari/RN, and the geosites Serra da Rajada and Monte do Galo, located in the municipality of Carnaúba dos Dantas/RN, are associated with the exposure of the granitic facies of the Acari Pluton (Figure 2). The formation and development of the granitic forms of these geosites are attributed to selective weathering, both subsurface and on the topographic surface (MAIA et al., 2018), and to the process of evorsion, in the case of the potholes that constitute the granitic microforms of the Poço do Arroz and Marmitas do Rio Carnaúba geosites.

Figure 2 – Partial view of the Geosites Açude Gargalheiras (A), Marmitas do Rio Carnaúba (B), Serra da Rajada (C) and Monte do Galo (D). Microforms such as lunchboxes (E), Tafone (F) and Block Chaos (G).




Source: prepared by the authors (2023).

The reasons for the maintenance of these granitic forms, such as inselbergs (e.g., Serra do Cruzeiro/Acari) and inselgebirgs (e.g., Serra dos Cambucás/Acari and Serra da Rajada/Carnaúba dos Dantas), are associated with the greater spacing between discontinuity structures (e.g., faults, fractures, veins, and dikes) and the enrichment of granitic facies in quartz and/or potassium feldspar, which hinder the action of denudational processes, as well as saprolitization, thus preserving a massive rock (MIGÓN, 2006).

The maintenance of erosive forms (potholes), associated with the rocky beds of the Acauã and Carnaúba rivers, is directly related to the competence and capacity of the river flow, associated with the density of weakness planes and the mineralogical composition of the facies of the rock substrate. Potholes are commonly formed by swirling motion (vertical fluvial vortices/evorsion) provided by the water flow over bedrock (ORTEGA-BECERRIL; GARROTE, 2023).



However, it is believed that the genesis and evolution of these microforms are correlated with a series of factors, including the energetic collisions between the detrital sediments transported by river waters (e.g., sand and pebbles) and the density of structural discontinuities (e.g., fractures, faults, veins, dikes), which can be easily verified, both at the Marmitas do Rio Carnaúba and Poço do Arroz geosites, as well as by changes in morphology (channel narrowing) and an increase in downstream slope gradient, which enhance river competence or capacity, consequently leading to mechanical erosion of the bedrock (MEDEIROS; NASCIMENTO; CORDEIRO, 2023).

The Monte do Galo geosite, located in the headquarters of the municipality of Carnaúba dos Dantas, is an inselberg, with a height of ≈150m. This residual relief consists of a pegmatitic rock mass with a concave-convex morphology, resulting from denudational processes that eroded and removed the enclosing rocks of the Seridó Formation (e.g., micaxists). The term inselberg is generally applied to the relief produced by the lowering of the surrounding surface, constituting typical residual rock forms (<10 km²) (BASTOS et al., 2020), which can provide essential information associated with the geomorphological evolution of the terrains in which they occur.

Understanding the formation and development of these geomorphological elements, i.e., the processes associated with their genesis and evolution, as well as the unique scenic beauty of the landscape, constitute the raw material of geotourism. The quantity, diversity, and distribution of landforms, and the values (e.g., scientific, educational, touristic, cultural) associated with them, confer potential for geotourism development to the 21 geosites of the Seridó UNESCO Global Geopark.

**Geotourism: Strategy for Geoconservation and Local Development**

In the state of Rio Grande do Norte, as well as in northeastern Brazil, the coastline, despite any criticism of sun and beach tourism, is the main area for leisure and tourism. However, in the semi-arid Northeast, specifically in the central-southern region of Rio Grande do Norte, the territory of the municipalities of the Seridó UNESCO Global Geopark presents a unique natural landscape that has been attracting many tourists in recent years.

Nascimento et al. (2021) state that considering the scientific, educational, touristic value, and the low to moderate risk of degradation of the 21 geosites of the Seridó UNESCO Global Geopark, the geosites Mina do Brejuí, Cânions dos Apertados, Xiquexique, Açude Gargalheiras, and Monte do Galo are considered the most important. It is necessary for the government to create protected areas covering these geodiversity hotspots, in addition to raising awareness among the local community about the importance of geosites in scientific, educational, cultural, and economic spheres, for collective recognition.



Gray (2008) identifies four types of environments where there would be a higher concentration of geodiversity elements, which could be considered as geodiversity hotspots: areas with long and complex geological evolution; convergent plate margins; areas with rugged topography; and coastal zones, where terrestrial and marine processes interact within the same area. According to this classification, the Seridó UNESCO Global Geopark is considered a geodiversity hotspot because it is located in an area with a long and complex geological evolution.

According to Bétard and Peulvast (2019), geodiversity hotspots are defined as areas that host very high levels of geodiversity. These geological sites of interest are considered the richest (or most geodiverse) sectors, regardless of the scale evaluated, whether local, regional, national, or global.

The magnificent biological, historical, cultural, and social diversity of the Seridó UNESCO Global Geopark territory can be important allies in the conservation of geopatrimony, knowing that there are still weaknesses in the public spheres regarding specific legislation for the abiotic environment.

The Seridó UNESCO Global Geopark represents, according to UNESCO (2010), a unique and unified geographical area, where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development. These areas are not conservation units, nor a new category of protected area, but they offer the possibility of associating landscape and natural monument protection with tourism and regional development.

According to Lopes, Araújo, and Castro (2011), geotourism has emerged as a promising segment of tourism activity, with specific characteristics essential for the conservation of geopatrimony and the economic development of the involved communities. Geotourism involves visiting and interpreting sites with correlated geological and geomorphological resources, which, combined with the social, cultural, and historical aspects of destinations, constitute tourist attractions (SILVA et al., 2021).

Geotourism encompasses visiting and providing information about natural resources, with a focus on geodiversity, contemplation, and interpretation aimed at generating meaning and value for conservation (SILVA et al., 2021). It is important to highlight that due to the limited diffusion of the scientific significance and social importance of geosites by geoscientists, geotourism emerges as a necessary precursor to geoconservation (HOSE, 2011).

Carvalho Neta, Corrêa, and Bétard (2020) consider geotourism as an activity whose main attraction is the components of geodiversity (geology, geomorphology, pedology, and hydrology), aiming at their conservation, strengthening the territory's identity, and promoting awareness of geopatrimony and the well-being of local populations. UNESCO recommends that this tourism segment be recognized, widely disseminated, and valued in the territories of its geoparks.

One of the advantages of geotourism, according to Brilha (2005), is that it is not limited to specific seasons, nor does it depend on the habits of fauna or flora. Additionally, geotourism can boost the local economy through crafts with motifs related to geodiversity. In many cases, geotourism can be developed in places where other tourism segments are already established, complementing the tourism offerings, including urban areas, for example (JORGE; GUERRA, 2016).



## FINAL CONSIDERATIONS

The geographic space of the State of Rio Grande do Norte has peculiar characteristics and cannot be considered and managed as having a single tourist destination, sun and beach tourism. Regardless of the region in which this new tourist activity is practiced, geotourism can provide the development of regions not covered by beach and sun tourism, directing visitors to other areas of RN motivated not only by admiration of the landscape, but by knowledge of the processes what happened until it was formed and what processes continue to act on it.

In this work, geotourism is seen as an activity that is related to the valorization of geodiversity and conservation of geoheritage, and can assume a degree of strategic importance for the future of tourist development in Seridó Potiguar, in addition to allowing the sustainable development of the communities involved, without degrading or depleting the natural resources that are being used in this activity, raising awareness among the general public of the importance of their conservation and, increasing the identity of the territory and the well-being of the local communities involved

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